CONNECTING FARM COMPOSTS WITH AGRICULTURE INDUSTRY USERS
DEMONSTRATING COMPOST ASSETS WITH GROWERS

Final Report

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ABSTRACT

Selling compost can move excess nutrients off livestock farms and create revenue. To be a viable manure management tool, reliable markets need to be developed for agricultural composts. Potential large markets for composts in NYS include turf, landscaping and vineyards. This project examined the use of poultry and dairy manure-based composts as a topdressing on established turf, as a soil amendment for severely disturbed construction sites and as a surface application under the trellis of grapevines.

Turf: Compost application increased soil organic matter and resulted in excess soil P at the 4 study sites; bulk density improved at 2. Immature composts and/or those with high salt levels tended to burn the grass leaving voids that allow weed encroachment immediately after application. Turf quality did not improve over 3 years at sites that had been established on poor soil or sites that had extremely high use. Early spring green-up was reported on compost-treated plots at most sites.

Landscape: Compacted clayey soil amended with 50% compost had improved bulk density and supported plant growth.

Vineyard: There were no significant differences in berry weight, cluster weight, total crop yield, vine growth or organic matter between compost-applied and controls.

Key words: manure-based compost, athletic fields, established turf landscape, vineyard, turf maintenance, construction disturbed soil, compacted soil, poultry manure compost, dairy manure compost,

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SUMMARY

This document summarizes the results of a 3 year study conducted by Cornell Waste Management Institute and the Cornell Department of Horticulture. Funded by the New York State Energy Research and Development Authority, Cornell Cooperative Extension and the Cornell University Agricultural Experiment Station, this research was conducted to develop reliable markets for manure-based compost in New York State.

Established Turf

Compost use in turf maintenance was assessed at 4sites in NYS over 3 years. Dairy and poultry manure-based composts were topdressed at 2 rates on replicated plots along with control plots once in year 1 and twice in years 2 and 3. The impact on soils and turf quality was analyzed.

Compost properties have an effect on the suitability of that compost for use on turf. For application, if the compost is too wet it will clump, and if it is too dry it may be dusty. Particle size is also important. Large pieces such as wood chips present a challenge to even application and can remain on the lawn surface and smother the turf. High conductivity (or soluble salts) can indicate that the compost is not fully mature and may “burn” the grass leaving voids that allow weed encroachment. Immature composts may also have an ammonia odor. The organic matter (OM) content of composts varies and depends in part on whether the composting takes place on an improved surface or directly on soil that may then become mixed into the compost. Since increasing OM is often a motivation for using compost, a high OM content is desirable.

The use of manure-based composts on turfgrass improved soil organic matter, increased the pH of acidic soils, and decreased bulk density. Long-term application, on some sites, improved turfgrass quality, reduced weeds and increased grass cover. In addition, many of the managers at the sites reported earlier spring green-up on the compost-treated plots. High salt levels and immature composts had detrimental effects on some plots. Improvements due to compost additions may take time. At the end of this 3-year study, there was an upward trend in the compost treated plots at all but the site that had extreme use. On sites where fields were poorly constructed and where field-use is very high, compost additions could not overcome these limitations and did not result in significant improvements in turf quality.

Phosphorus (P) in the soil is important for plant establishment and growth. Levels of 4.5 ppm P are considered high and levels approaching 50 ppm may become an environmental issue due to potential leaching or runoff. Soil P increased significantly over time on all plots receiving compost to levels above 50 ppm.

Organic matter serves as a reservoir of nutrients and water in the soil, aids in reducing compaction and surface crusting, and increases water infiltration. For turf, values between 7 and 10% are considered good levels of organic matter. Soil organic matter levels increased significantly over time with all compost types at all sites.

Physical properties of the soil have an effect on how well roots can penetrate the soil and the ability of the plant to take up nutrients and water. Bulk density of all treatments at all sites decreased due to the core aeration performed as part of the experiment. In addition, compost resulted in lower bulk density at 2 of 4 sites. Aggregate stability refers to the ability of soil aggregates to resist disruption when outside forces are applied. At all sites aggregate stability fell within acceptable range throughout the research. Despite the fact that OM increased at all sites and is supposed to increase aggregate stability, it increased at only at one site.

Water infiltration rates at all sites were acceptable at the start and compost additions had little effect.

LANDSCAPE REMEDIATION

Creating viable landscapes on the compacted soils resulting from the building process is a tremendous challenge. A Cornell University horticulture class designed, amended and installed new landscaping where soils had been severely degraded due to construction. The objective was to amend a compacted clayey soil with two types of compost so that beneficial levels of soil density, aeration and drainage could be achieved. A new landscape was created on the site to take advantage of these improved conditions and soils and plant growth were monitored.

Soil from the site was amended in varied proportions (25, 50 and 75% by volume) in the laboratory with a poultry and a dairy-manure compost. The soil was mixed and recompacted and tested for density, macroporosity and drainage. Fifty percent amendment reduced the bulk density of the soil to below root inhibiting levels and that level of both composts was added to the soil to a depth of 18 inches.
Soil properties of the beds were monitored over 3 years to evaluate how long the benefits of compost amendment last. Bulk density remained below root inhibiting levels after the third growing season and the landscape has thrived.

VINEYARD

This study tracked changes over 3 years in soil chemistry and vine productivity resulting from one compost application . There were no significant differences in berry weight, cluster weight, total crop yield, berries per cluster, cluster number, petiole nutrient levels or Brix between treatments and controls.

SECTION 1

USING MANURE-BASED COMPOSTS IN TURF MANAGEMENT

OVERVIEW

Turfgrass conditions on athletic fields are not only an aesthetic concern, but can have an effect on play and safety. Athletic fields are prone to compaction due to heavy traffic, use of the fields when conditions are wet, and the weight of vehicles used on the fields. Wet and/or hard surfaces can cause injury to the turf and the players. Compaction restricts rooting depth, reducing the uptake of water and nutrients by plants, which can lead to poor growth and loss of turf cover. The addition of organic matter to the soil promotes aggregation of soil particles, increasing porosity and reducing bulk density to make less compact soil. Composting livestock manure and selling it can help farms move excess nutrients off the farm and can be a source of revenue. Manure-based compost can be used on athletic fields to add and maintain organic matter content.

TURFGRASS INDUSTRY SURVEY

A survey of turfgrass managers across the state was conducted in an effort to identify the current knowledge regarding compost use, and the industry-specific goals and concerns in regard to compost use (Appendix A). Fifty surveys were completed by managers responsible for the maintenance of turf and 61 by those responsible for establishing turf on either athletic fields or lawns. Results of the survey showed that compost was used routinely in maintenance of turf by 24% of the respondents, but only 1/3 of these used it on athletic fields. Very few of these used manure-based composts. The most common concerns turf managers had about using compost was weed seeds and pH. Current users were concerned about particle size and inconsistency from batch to batch. The most common challenge faced by the respondents in maintaining their athletic fields was in scheduling, as it is extremely difficult to get products down at the proper times. Initial construction of the fields (if they were built on poor soils) compaction, overuse, and resources (money for equipment and materials) were additional challenges in maintaining turf.

RESEARCH DESIGN

Field research was conducted at four sites in New York State from September 2003 through July 2006. At each site there were six treatments and 3 replicates for each treatment distributed in a randomized block design. Treatments were applied five times. The composts used were analyzed prior to application for both pathogen levels (fecal coliforms and *salmonella*), and compost properties. Soil samples from the 18 plots at each site were taken for analysis of chemical and physical properties at the beginning (before application of treatments) and four additional times throughout the study. Turf quality ratings were done monthly during the growing season by trained turf professionals. Water infiltration rates were determined at the beginning and end of the study.

Sites

Two of the sites used in this study were located in Western New York (Clarence and Rochester), and two were in south eastern New York in Orange County (Pine Island and Minisink). The sites were very different in their use and management. In Clarence, the experimental plot was on the far edge of a baseball field in a park, and was more like a lawn than a sports field in traffic intensity and use. It was mowed weekly at 2" and did not receive supplemental irrigation, nor was there any weed control. The soil texture is a loam (43% sand, 17% clay). In Rochester, the experimental plot was on a soccer field used by both schools and the community for about 2 games per week. The site started out with about 60% grass, 30% weeds and 10% bare spots. It had moderate traffic during the study. The field was mowed at 2 ½" approximately every 10 days and weed control was not used. The soil texture is a very fine sandy loam (61% sand, 10% clay). At Pine Island, the experimental plot was on a community recreation field that hosts about 25-30 baseball games per season and a summer recreation program from July to August. It was mowed weekly at 3". The soil here is a coarse sandy loam (66% sand, 11% clay) that was established on rubble and had no more than 2 to 2 ½" of actual soil. At Minisink, the experimental plot was on a high school sports field with excessive use and highly compacted soils. It was used for high school football practice and games. It also served as the daily physical education site. The field was mowed twice a week at 2 to 2 ¼". Weed control was used. The soil texture is a sandy loam (68% sand, 8% clay).

Composts

Two types of manure-based compost (dairy and poultry manure) from four different suppliers were used in this project. Table 1-1 shows the average range of properties of composted dairy and poultry manures used at the four sites for the three years of the study. The compost properties listed in the table above can have an effect on the suitability of that compost for use on turf. The moisture content can have an effect on the ability to spread the compost on the turf. At Pine Island and Minisink, where the moisture content of the dairy compost was above 60%, it was difficult to spread evenly without getting clumps, and the poultry, although easy to spread, tended to be dusty. The more alkaline pH in the poultry compost used in Clarence and Rochester indicated that the compost could have been more mature. There was a definite ammonia smell with some of the applications. This caused a problem for those spreading it, as well as those playing on it. The salt concentration of the poultry compost at Minisink caused some problems with "burning" (dehydration of) the turf. Organic matter was high (approximately 50% or greater) for all composts except the dairy compost used in Clarence and Rochester. This was due to the fact that this compost was made in windrows on a soil pad. The phosphorus level was high in both poultry composts. The C:N ratio was good for all composts.

Table 1-1: Average Range of Properties of Composted Dairy and Poultry Manures Used Over Three Years

Compost Property	Dairy Compost for Clarence and Rochester	Poultry Compost for Clarence and Rochester	Dairy Compost for Minisink and Pine Island	Poultry Compost for Minisink and Pine Island
Moisture (%)	33 – 60	27 – 39	67 – 75	20 – 27
pH	7.9 – 8.5	8.8 – 8.9	7.4 – 7.9	6.9 – 8.0
Soluble salts (mmhos/cm)	1.5 – 4.3	7.7 – 9.9	1.0 – 4.4	10.9 – 13.1
Organic Matter (% dm basis)	23 – 39	44 – 56	49 – 64	35 – 43
Total Nitrogen (% dm basis)	1.2 – 1.6	1.8 – 2.2	1.6 – 1.9	2.5 – 3.0
Phosphorus (% dm basis as (P_2O_5)[3]	1.0 – 1.4	5.0 – 6.4	1.1 – 2.1	4.0 – 5.7
C:N ratio	11 – 12	11 – 14	16 – 21	7 - 9

Experimental Design

Each field had a 34 x 70 foot area designated for the experiment. There were eighteen 10 x 10 foot plots with a 2-foot buffer around each for 3 replicates of 6 treatments. Each site received 5 applications of compost. Because composts varied in moisture content and they were applied on a volume basis, the dry weight and thus the quantity of nutrients, organic matter and other constituents added varied (Table 1-2).

Treatments started in September of 2003 and continued in June and September of 2004 and 2005. The treatments were as follows:

- ¼" layer of poultry manure compost (¼" P)
- ½" layer of poultry manure compost (½" P)
- ¼" layer of dairy manure compost (¼" D)
- ½" layer of dairy manure compost (½" D)
- Fertilized control (no compost) (F/NC)
- Unfertilized control (no compost) (NF/NC)

Table 1-2: Average Tons of Compost Dry Matter Applied per Acre at Four Sites by Treatment

Site	¼" P	½" P	¼" D	½" D
Clarence	11.7	22.7	12.5	25.5
Rochester	11.1	22.1	12.7	25.8
Pine Island	14.2	28.8	6.6	12.5
Minisink	14.4	28.9	6.6	13.4

All plots, except the unfertilized control received nitrogen fertilizer (no phosphorus) at the rate of 1 lb/1000 sq. ft. At Minisink, however, after September 2003, all plots, including the unfertilized control, received fertilizer.

Prior to application of compost, soil samples were taken for chemical and physical analysis. The plots were then core aerated. Compost was weighed and applied on a volume basis (two bushel baskets for the ¼" rate and 4 for the ½" rate) and raked into an even layer on the plots. The plots were then core aerated a second time to help work the compost into the soil. Unfertilized control plots were then covered with tarps and fertilizer was applied to the remaining plots. Water infiltration rates were determined at the beginning of the study in September 2003 and at the end in June 2006. Individual plots at all sites were rated approximately monthly during the growing season for percent grass, weeds and bare, and overall turfgrass quality rating using the National Turfgrass Evaluation Program (NTEP) method (Appendix B).

RESULTS

Soil Chemical Properties

pH. Soil pH has an effect on the availability of soil nutrients. Most minerals and nutrients are more soluble or available in acid soils than in neutral or slightly alkaline soils. A pH range of approximately 6 to 7 promotes the most readily available plant nutrients. Compost application did not have an effect at Clarence and Rochester where the pH started at 7.4, averaged over all plots, and ended at about 7.6. At Pine Island the application of poultry compost over three years did significantly increase the pH from 6.1 to 7.2 for the ¼" treatment plots and from 5.0 to 7.3 for the ½" treatment plots (See Appendix C for statistical analysis details). The addition of ½" dairy compost at Pine Island increased the pH from 5.9 to 7.0. At Minisink, all of the plots, including the control plots, showed an increase in pH over the course of the study (from just above 6 to around 7).

Manganese and Iron. Both manganese (Mn) and Iron (Fe) are micronutrients whose availability can be affected by pH. In both cases, the higher the pH, the less available are Mn and Fe. Iron is essential for chlorophyll synthesis and can thus help with turfgrass color. Acceptable iron levels are approximately 2.5 to 5.0 mg/kg. Compost application did not have much affect on soil iron levels at any of the sites. Manganese plays a role in photosynthesis and helps to suppress both leaf and root diseases. When the pH is below 7.0, adequate levels of manganese are in the range of 4.6 – 12 mg/kg, while levels of 12 – 20 are considered high and above 20 very high. At pH 7.0 and above, 5.1 – 15 mg/kg is adequate, 15 – 50 high and above 50 very high. The soil manganese level, increased to the high range with the use of poultry compost at all sites (Table 1-2). At Clarence and Rochester, only the ½" poultry plots were affected, and it took 3 years for the increase to be evident. Since the pH was above 7 at all times at Clarence and Rochester, manganese levels were adequate in the dairy and control plots, while the poultry plots were high. At the other 2 sites, the increase was immediate and was seen at both levels of poultry applications. At both Pine Island and Minisink, where pH was below 7, manganese levels were high for all plots at all times.

Table 1-3: Beginning and Ending Average Soil Manganese Levels (mg/kg) at Four Sites by Treatment. Values followed by different superscripts in each row for each site separately are significantly different (p < 0.05) (ie. ¼" P is not different from start date to end date at Clarence or Rochester, but it was significantly changed at PI and Minisink).

	Clarence		Rochester		Pine Island		Minisink	
Treatment	Sept 03	June 06	Sept 03	June 06	Sept 03	June 06	Sept 03	June 06
¼" P	18.9	20.9	20.8	24.7	23.2^{a}	45.9^{b}	20.3^{a}	42.4^{b}
½" P	16.9^{a}	38.0^{b}	17.8^{a}	42.7^{b}	20.9^{a}	55.9^{b}	20.9^{a}	49.2^{b}
¼" D	18.7	17.3	20.4	16.7	19.3	25.5	18.5	22.3
½" D	20.2	22.6	21.5	23.0	24.8	24.5	21.5	24.6
F/NC	18.8	16.5	19.7	15.9	19.7	25.8	21.3	23.5
NF/NC	18.7	13.7	20.7	19.6	22.6	25.6	19.1	30.6

Phosphorus. Phosphorus (P) in the soil is important for both agronomic production and environmental protection. Levels of 4.5 mg/kg P are considered to be high and levels approaching 50 mg/kg may become an environmental issue as they are more prone to discharge P to the environment in water runoff. Soil phosphorus, which started high at Pine Island and Minisink and was optimum in Clarence and Rochester, increased significantly over time at all four sites on plots receiving compost (Table 1-3 and Figure 1-1). There was an immediate effect on soil P levels from the poultry compost, but it took longer to see an effect from the dairy compost. By the end of three years, all compost treated plots had significantly greater soil P levels than non-compost treated plots at three sites. At Minisink though, as P levels increased in the non-compost treated plots as well, only the ½" compost levels (both poultry and dairy) had greater soil P.

Table 1-4: Beginning and Ending Average Soil Phosphorus Levels (mg/kg) at Four Sites by Treatment. Values followed by different superscripts in each column are significantly different ($p < 0.05$) (ie. there are no differences between treatments at Clarence in Sept 03. In June 06, all of the compost treatments are significantly different than the no compost treatments, but they are not significantly different from each other).

	Clarence		Rochester		Pine Island		Minisink	
Treatment	Sept 03	June 06	Sept 03	June 06	Sept 03	June 06	Sept 03	June 06
¼” P	3.3	164.6^{a}	7.4	179.8^{a}	15.1	237.3^{a}	40.4	194.9^{ab}
½” P	4.7	160.5^{a}	6.6	135.1^{a}	11.1	236.9^{a}	40.9	274.0^{a}
¼” D	4.2	142.8^{a}	5.8	86.7^{a}	17.3	158.5^{a}	35.3	173.3^{ab}
½” D	5.8	94.6^{a}	7.3	125.0^{a}	16.3	181.6^{a}	36.0	228.5^{a}
F/NC	5.7	11.0^{b}	7.0	11.0^{b}	20.1	38.1^{b}	33.4	73.0^{b}
NF/NC	4.3	9.0^{b}	6.0	9.5^{b}	14.5	38.9^{b}	30.4	68.3^{b}

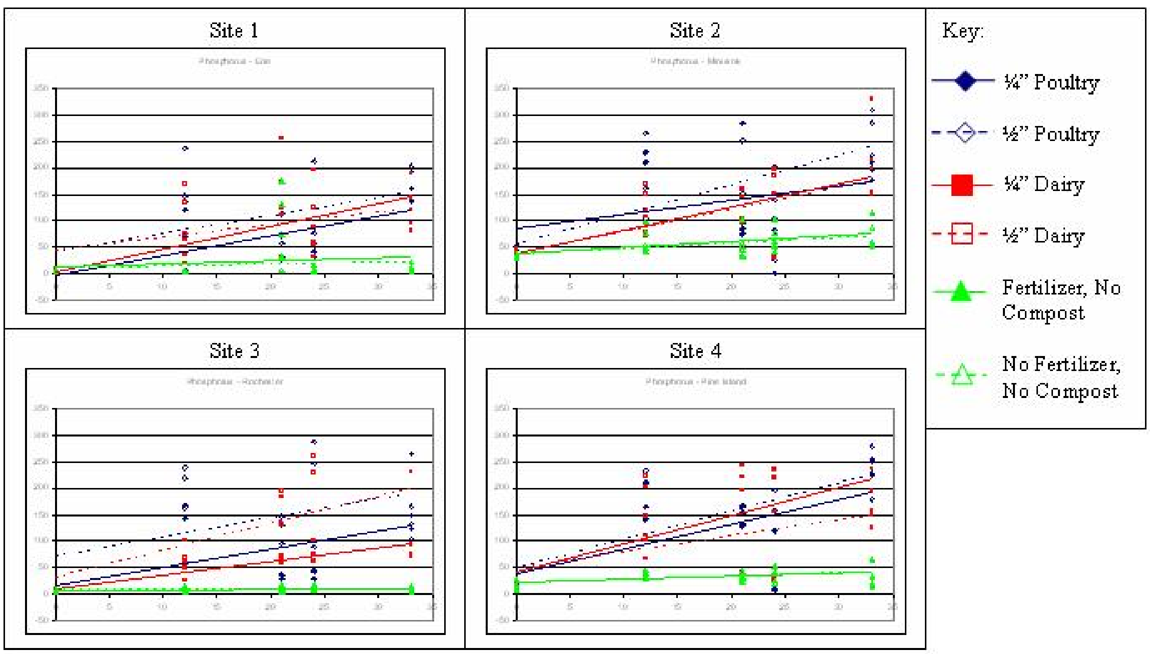


Figure 1-1: Soil Phosphorus Levels for Each Treatment Over Time at Four Sites.

<u>Organic Matter.</u> Healthy productive soils have a good supply of organic matter. Organic matter serves as a reservoir of nutrients and water in the soil, aids in reducing compaction and surface crusting, and increases water infiltration into the soil. For turf, values between 7 and 10% are considered acceptable. Soil organic matter levels increased significantly over time with all compost types and levels at all sites, except Clarence, where ¼” dairy compost did not cause a significant increase in organic matter over the course of the study (Table 1-4 and Figure 1-2). Compost application at Rochester and Pine Island, especially poultry compost brought the soil organic matter up from approximately 5% to between 8 and 16%, greatly improving the organic matter content at these sites.

Table 1-5: Beginning and Ending Average Soil Organic Matter Levels (%) at Four Sites by Treatment. Values followed by different superscripts in each row for each site separately are significantly different ($p < 0.05$).

	Clarence		Rochester		Pine Island		Minisink	
Treatment	Sept 03	June 06	Sept 03	June 06	Sept 03	June 06	Sept 03	June 06
¼" P	8.1^{a}	9.7^{b}	5.3^{a}	15.1^{b}	4.0^{a}	12.1^{b}	8.1^{a}	15.1^{b}
½" P	8.2^{a}	12.8^{b}	5.1^{a}	18.3^{b}	4.6^{a}	15.6^{b}	9.2^{a}	18.3^{b}
¼" D	8.5	10.2	5.1^{a}	12.0^{b}	4.6^{a}	8.5^{b}	7.2^{a}	11.5^{b}
½" D	8.0^{a}	11.1^{b}	5.6^{a}	15.3^{b}	4.2^{a}	10.6^{b}	9.5^{a}	13.8^{b}
F/NC	8.7	7.6	5.4	10.0	4.6	5.5	9.5	10.4
NF/NC	8.3	7.8	5.4	11.7	4.6	5.2	9.3	9.4

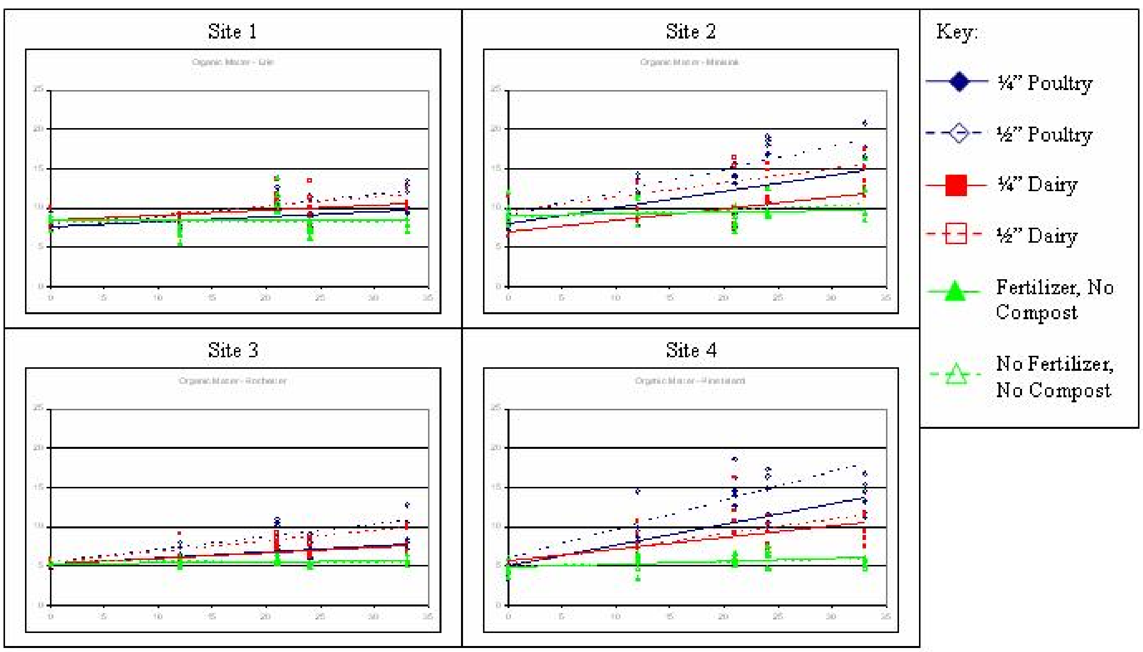


Figure 1-2: Soil Organic Matter Levels for Each Treatment Over Time at Four Sites.

Soil Physical Properties

Bulk Density. The addition of organic matter is considered to have a profound effect on soil physical properties. It stabilizes and holds soil particles together as aggregates, helps soil to resist compaction, promotes water infiltration and reduces runoff. It also improves the soil's ability to store and transmit air and water, and makes the soil more friable and easier for roots to penetrate. Considering the increase in organic matter that occurred due to the addition of compost, one would expect an improvement in the physical characteristics of the soils as well. Bulk density of the soils at all sites decreased over the course of the study on all plots due to the core aeration performed as part of the experiment. In addition, bulk density at the end of the study was significantly lower in one or more compost treated plots over the controls at two of the sites (Table 1-5). At Clarence, the ½" dairy treated plots had significantly lower bulk density than no fertilizer, no compost plots. In Rochester all of the compost treated plots except ¼" dairy had significantly lower bulk density than the no compost plots. Although there were no significant differences between plots at the end of the study in Pine Island and Minisink, the compost treated plots had lower bulk density than controls in September 2005.

Table 1-6: Beginning and Ending Average Soil Bulk Density (g/cm^3) at Four Sites by Treatment. Values followed by different superscripts in each column are significantly different ($p < 0.05$).

	Clarence		Rochester		Pine Island		Minisink	
Treatment	Sept 03	June 06	Sept 03	June 06	Sept 03	June 06	Sept 03	June 06
¼" P	1.4	0.9^{ab}	1.4	0.9^{ab}	1.6	1.2	1.6	0.9
½" P	1.3	0.9^{ab}	1.5	0.7^{a}	1.6	1.3	1.6	0.8
¼" D	1.3	1.0^{ab}	1.5	1.2^{bc}	1.6	1.2	1.6	1.1
½" D	1.3	0.8^{a}	1.4	0.2^{ab}	1.6	1.2	1.5	0.9
F/NC	1.4	1.1^{ab}	1.5	1.3^{c}	1.5	1.3	1.5	1.1
NF/NC	1.3	1.2^{b}	1.5	1.3^{c}	1.6	1.1	1.5	1.0

Aggregate Stability. Aggregate stability refers to the ability of soil aggregates to resist disruption when outside forces (usually associated with water) are applied. Since aggregation affects erosion, movement of water, and plant root growth, it is desirable to have aggregates that are stable against rainfall and water movement. A value of 20% is considered low, and 70% is considered high. Although the addition of organic matter is supposed to increase the aggregate stability of the soil, the only site at which aggregate stability was significantly higher in any of the compost treated plots over the controls was in Rochester where the ½" poultry and dairy plots both had significantly greater aggregate stability than the unfertilized control (they also had the greatest increase in organic matter). However, aggregate stability at all sites fell within the 20 – 70% range and probably did not need improvement.

Water Infiltration Rate. The infiltration rate of a soil is the rate at which water soaks into it, measured in this study as centimeters of water soaking in per hour (cm/h). If the steady infiltration rate is very low, say less than 0.5 cm per hour, even very gentle rain falling on moist medium will cause surface ponding or runoff of water. The surfaces of playing fields will remain mushy for days after rain, allowing play to cause much damage to the turf. Infiltration rate is a useful indicator of aeration in the soil. Good aeration is probable if the steady infiltration rate is greater than 2 cm/h. Poor turf growth can be traced to poor aeration of the root zone. The approximate steady infiltration rate of loam soils is between 0.5 and 2.0 cm/hour depending on type of loam. Initial infiltration rates at all sites were within this range (Table 1-6). At Clarence, both poultry treated plots and at Rochester the ½" poultry plots had significantly higher infiltration rates than the control plots at the end of the study. There were no significant differences between plots at the end of 3 years at Pine Island or Minisink.

Table 1-7: Beginning and Ending Average Water Infiltration Rates (cm/h) at Four Sites by Treatment. Values followed by different superscripts in each column are significantly different ($p < 0.05$).

	Clarence		Rochester		Pine Island		Minisink	
Treatment	Sept 03	June 06	Sept 03	June 06	Sept 03	June 06	Sept 03	June 06
¼" P	12.7^{ab}	35.5^{a}	6.3	11.8^{ab}	18.5^{a}	5.5	1.4	5.0
½" P	10.2^{ab}	42.6^{a}	5.6	22.3^{a}	25.2^{a}	6.1	1.1	6.8
¼" D	15.3^{a}	21.7^{ab}	4.4	11.4^{ab}	6.3^{ab}	5.5	1.0	6.9
½" D	9.4^{ab}	24.3^{ab}	7.6	18.1^{ab}	11.3^{ab}	7.2	1.3	6.9
F/NC	6.4^{b}	13.8^{b}	6.3	9.0^{b}	12.1^{ab}	5.6	1.1	4.7
NF/NC	11.8^{ab}	12.1^{b}	4.3	8.6^{b}	3.7^{b}	13.7	1.3	7.9

TURF QUALITY

Overall turfgrass quality (TQ) is a measure of aesthetics (i.e. density, uniformity, texture, smoothness, growth habit and color), and functional use. The most common way of assessing turfgrass quality is a visual rating system that is based on the turfgrass evaluator's judgment. Quality is based on 9 being best and 1 being poorest. A rating of 6 or above is generally considered acceptable. The average TQ rating over all plots at the beginning of the study was just under being considered acceptable at Clarence (5.4), Rochester (5.3) and Pine Island (5.6), and low at Minisink (3.8). The addition of compost alone appeared to be of benefit to turfgrass quality at Minisink and Rochester only. Table 1-7 shows beginning and ending values of turfgrass quality ratings and Figure 1-3 shows turfgrass quality rating trends for June and September only over the study period at each site. At Clarence, all treatment plots except the unfertilized control showed an increase in turfgrass quality indicating that there was no additional improvement with the application of compost over and above that of applying a nitrogen fertilizer. At Pine Island, all of the turgrass quality ratings decreased. In Minisink, the application of ½" poultry compost increased turfgrass quality ratings significantly from 3.4 to 5.7, and in Rochester, both the ½" poultry and the ¼" dairy treatments increased turfgrass quality ratings significantly. The upward trend in turfgrass quality in the compost treated plots at all sites but Minisink suggests that there may be a potential for long-term benefit of compost applications.

Table 1-8: Beginning and Ending Average Turf Quality Ratings at Four Sites by Treatment. Values followed by different superscripts in each row for each site separately are significantly different ($p < 0.05$).

	Clarence		Rochester		Pine Island		Minisink	
Treatment	Sept 03	June 06	Sept 03	June 06	Sept 03	June 06	Sept 03	June 06
¼" P	5.8^{a}	6.8^{b}	5.2	5.8	5.6^{a}	4.6^{b}	3.5	5.8
½" P	4.9^{a}	6.2^{b}	5.3^{a}	6.2^{b}	5.5^{a}	4.3^{b}	3.4^{a}	5.7^{b}
¼" D	5.1^{a}	6.6^{b}	5.3^{a}	5.9^{b}	5.8^{a}	5.2^{b}	4.3	5.5
½" D	5.9^{a}	6.7^{b}	5.4	5.8	5.7^{a}	4.8^{b}	4.2	5.7
F/NC	5.4^{a}	6.3^{b}	5.4	5.5	5.6^{a}	4.5^{b}	4.1	4.8
NF/NC	5.3	5.6	5.2	5.4	5.5^{a}	4.3^{b}	3.3	4.9

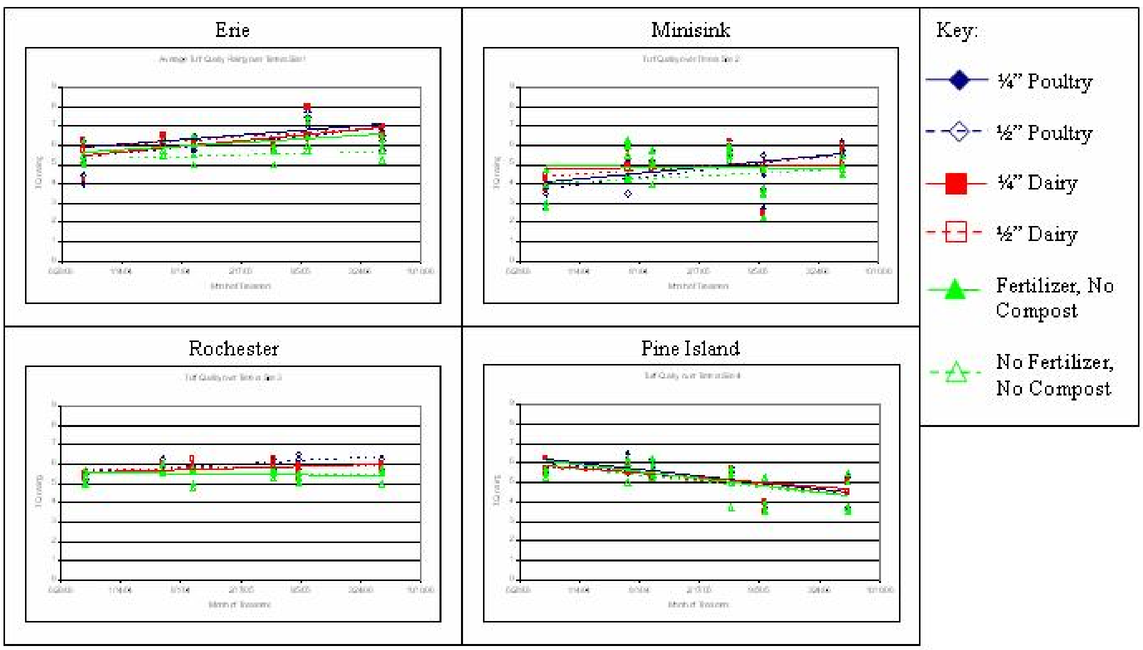


Figure 1-3: Turfgrass Quality Ratings for Each Treatment in September and June Over Time at Four Sites.

Poultry compost (with its high soluble salt concentration) tended to burn the grass in the first month after application when applied at the ½" rate, especially at high traffic sites. After that, percent grass increased in compost treated plots over the unfertilized, no compost plots, but not to any greater extent than the fertilized, no compost plots at three of the sites. However, in Rochester, where field use was moderate, the compost treated plots had significantly more grass and less weeds than both the fertilized and unfertilized control plots (Figures 1-4 and 1-5). In 2004 at Minisink, there was a problem with Knotweed, which was especially apparent in the ½" poultry treated plots. As Knotweed is tolerant of salt, it is possible that the high salt content of the poultry compost may have exacerbated the problem.

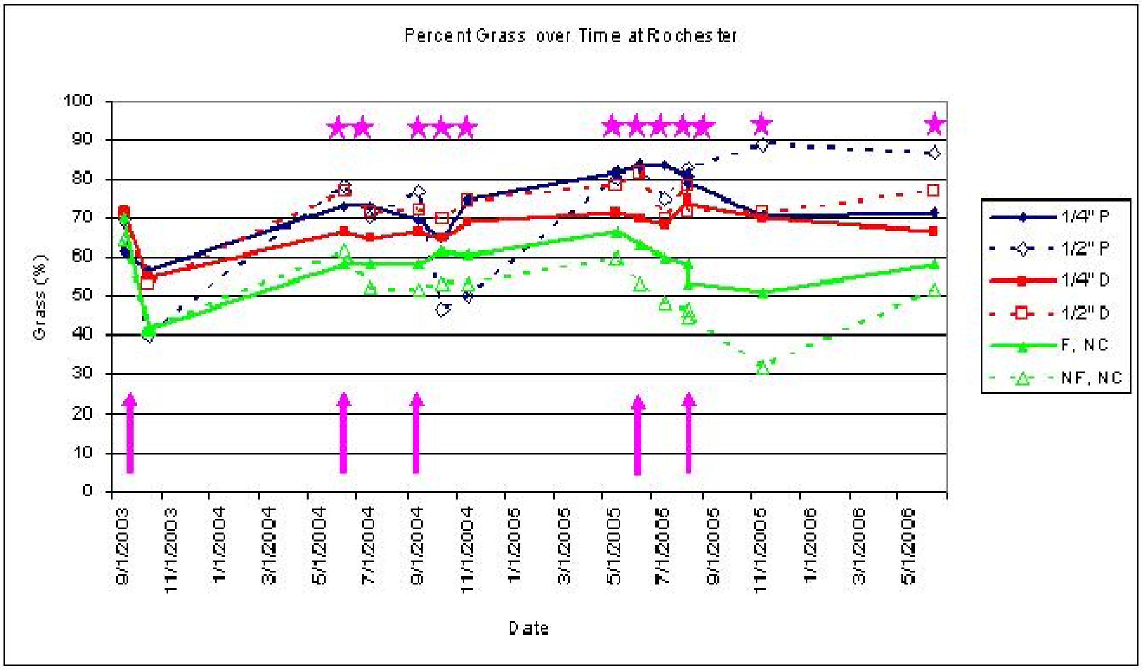


Figure 1-4: Average Percent Grass Over Time at Rochester by Treatment. Pink arrows show compost application dates and pink stars show dates at which there were significant differences in percent grass between one or more treatments.

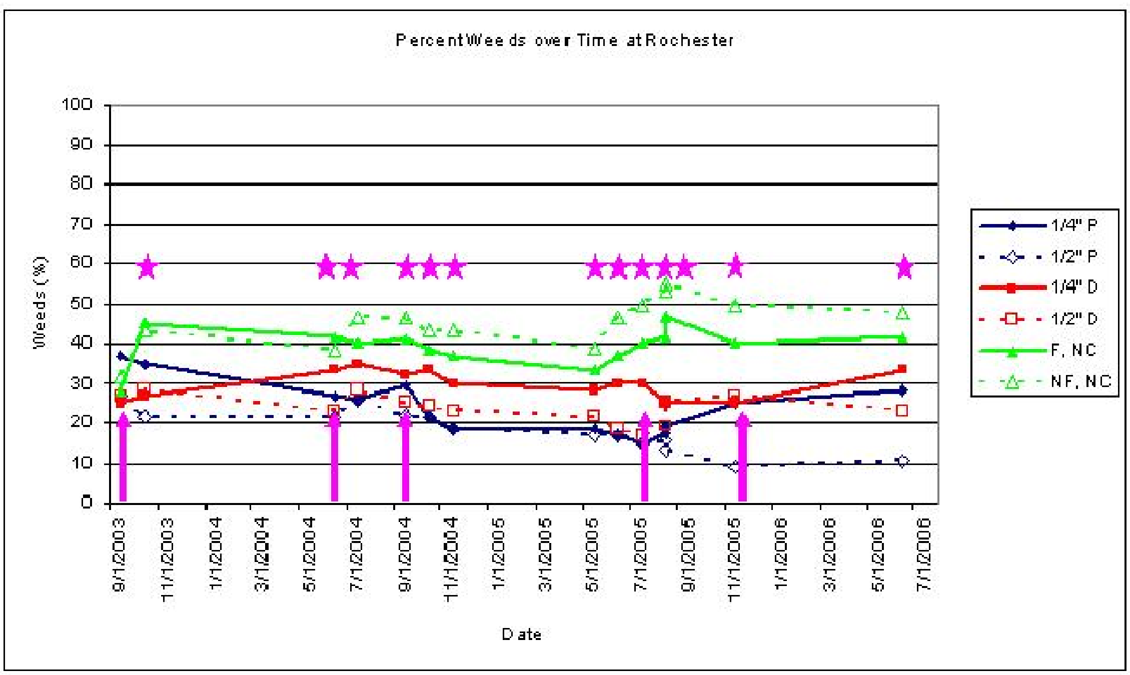


Figure 1-5: Average Percent Weeds Over Time at Rochester by Treatment. Pink arrows show compost application dates and pink stars show dates at which there were significant differences in percent grass between one or more treatments.

CONCLUSIONS

The use of manure-based composts on athletic fields improves soil organic matter content, increases the pH of acidic soils closer to neutral, and decreases bulk density. Over the long-term, on some sites, it can improve turfgrass quality although in general, compost and fertilizer had similar impacts. At one site compost increased the amount of grass and decreased the amount of weeds. In addition, many of the managers at the sites reported earlier spring green-up on the compost treated plots, as well as better color in the poultry compost treated plots (Appendix D). Improvements due to compost additions may take time. High salt levels and immature composts can have short-term detrimental effects such as burning of the grass and exacerbation of weed problems. Application of manure-based composts increases soil P levels high enough to cause concern that elevated runoff or leaching losses of P may occur. Before using any compost, it would be advisable to test the soil to see where deficiencies lie and to test the compost to make sure it is not too high in soluble salts and has a moisture content and particle size that will be conducive to application.

SECTION 2

USING MANURE-BASED COMPOSTS FOR LANDSCAPE REMEDIATION

OVERVIEW

During 2003-2004, Cornell University's Horticulture class 491-492, taught by Nina Bassuk and Peter Trowbridge, designed, amended and installed a new landscape (the Student Garden) between Warren Hall and Mann Library that had been severely degraded due to construction damage caused by the addition to Mann Library. This made an excellent test site for the use of manure-based composts during the remediation of the highly compacted clayey soil. Compacted soils are the ubiquitous result of urbanization and the building process. Creating viable landscapes on these sites is a tremendous challenge for professionals in landscape architecture and horticulture. The objective of this project was to amend a compacted clayey soil with two types of compost in a landscape setting so that beneficial levels of soil density, aeration and drainage could be achieved. A new landscape was created on the site to take advantage of these improved conditions and plant growth was monitored.

RESEARCH DESIGN

Selection of Compost Amendment Amount

Based on research conducted by Rivenshield and Bassuk[1] at Cornell's Urban Horticulture Institute, it appears that compacted soils can be made productive again if appropriate types and volumes of composted organic matter are incorporated. Soil bulk densities were reduced to below root restricting thresholds with the addition of 33% compost in a sandy loam soil and 50% compost in a clayey soil. With this in mind, a thorough characterization of the 'before' conditions at the Mann Library site was done, including soil texture and density, spatial variability, drainage, water-holding capacity, nutrient and microbial status.

Soil from the site was taken to a laboratory and amended with two types of composts (poultry and dairy) at increasing levels to predict how much would be necessary to create beneficial conditions for plant growth. The dairy compost (that used in the turf project for Pine Island and Minisink – Table 1-1) was manure bulked with wood and bedding and food scraps. The compost was made on a dirt pad in windrows with a high turning frequency. The poultry compost was poultry manure bulked with wood and bedding. This was also made on a dirt pad in windrows with a high turning frequency. Soil was taken from the site and roughly sieved through an 8mm sieve. Twenty-five, 50-and 75% compost and no compost was added by volume to the soil. The soil was mixed and recompacted using a standard Proctor hammer protocol and

[1] Rivenshield, A. and Bassuk, N.L. 2007. Using Organic Amendments to Decrease Bulk Bensity and Increase Macroporosity in Compacted Soils. *Arboriculture & Urban Forestry*. 33(2):140-146.

tested for density, macroporosity and drainage. Four replicates of each type of compost soil mixture were analyzed. Table 2-1 shows the bulk density and macroporosity of the initial soil tests run in the laboratory. Fifty percent amendment reduced the bulk density of the soil to below root inhibiting levels (1.45g/cc) for the silty clay soil after re-compaction, and that level of both composts was added to the soil on site.

Table 2-1: Average Bulk Density and Macroporosity for Different Volumes of Soil and Compost. Values followed by different superscripts in each column are significantly different ($p < 0.05$).

Compost	% Volume	Bulk Density	Macroporosity
None	0	1.81[a]	0.59[a]
Poultry	25	1.65[b]	0.54[a]
Poultry	50	1.51[c]	1.24[a]
Poultry	75	1.36[d]	1.43[a]
Poultry	100	1.22[e]	1.49[a]
Dairy	25	1.56[bc]	0.84[a]
Dairy	50	1.28[de]	1.08[a]
Dairy	75	0.91[f]	1.55[a]
Dairy	100	0.51[g]	4.99[b]

Remediation of the Site

The original soil was then taken from the site and amended with 50% compost (by volume), half with the poultry manure compost and half with the dairy manure compost. The amended soils were returned to the site and spread to a depth of 18 inches. No further compost additions were made. The site was approximately 75 x 50 feet. Figure 2-1 shows pictures of the site and the soil prior to compost amendment. Because this was a “real world” project seeking to improve a degraded landscape, there were no unamended control plots. Figure 2-2 shows pictures of the amended soil being brought on site in the fall of 2004 and the students planting the beds the following spring. Figure 2-3 shows the initial plantings in the triangle in the spring of 2004. The site was divided into the “triangle” (shown below in Figure 2-1) and “Warren side” (which can be seen in the far right corner of the right hand picture in Figure 2-2). Both the poultry and the dairy manure compost-amended soils were used in the triangle and Warren side. Soil samples were taken in quadruplicate from the four different site/compost combinations on 12/3/04, 11/3/05 and 9/21/06 and tested for density, macroporosity and drainage.

Figure 2-1: Mann Library Site after Construction (left) and Initial Soil at the Site (right).

Figure 2-2: Amended Soil Being Brought on Site (left) and Students Planting Beds (right).

Figure 2-3: Initial Planting in the "Triangle".

RESULTS

Table 2-2 shows the bulk density and Table 2-3 shows the macroporosity of the four site/compost combinations over time. The bulk density and the macroporosity remained constant over time for each of the four site/compost combinations, indicating that the benefits of compost addition lasted over three growing seasons. Figure 2-4 shows a picture of a portion of both Warren and the triangle three years after the initial planting. All site/compost combinations are thriving and the bulk density of the soil remains below root inhibiting levels (1.45g/cc) for silty clay soil after re-compaction.

Table 2-2: Average Bulk Density of the Soil at the Four Site/Compost Combinations Over Three Years. Values followed by different superscripts in each column are significantly different ($p < 0.05$).

Date	Adams Triangle	Adams Warren	Cornell Triangle	Cornell Warren
12/3/04	0.81[a]	1.13[a]	0.85[a]	1.01[a]
11/3/05	0.67[a]	1.12[a]	0.82[a]	0.98[a]
9/21/06	0.80[a]	1.15[a]	0.97[a]	0.94[a]

Table 2-3: Average Macroporosity of the Soil at the Four Site/Compost Combinations Over Three Years. Values followed by different superscripts in each column are significantly different ($p < 0.05$).

Date	Adams Triangle	Adams Warren	Cornell Triangle	Cornell Warren
12/3/04	6.1[a]	3.3[a]	4.0[a]	3.2[a]
11/3/05	3.0[a]	3.3[a]	3.8[a]	3.9[a]
9/21/06	3.8[a]	3.0[a]	4.3[a]	4.1[a]

Figure 2-4: Three Years After Initial Planting.

CONCLUSIONS

The landscape is thriving and the bulk density of the soil remains below root inhibiting levels three years after the compost-amended soils were established. The use of manure-based compost in soil remediation of construction sites can have lasting benefits for the growth and health of plants.

SECTION 3

USING MANURE-BASED COMPOSTS IN VINEYARDS

OVERVIEW

Compost represents an underutilized resource in vineyards. Dairy and horse farms in the Finger Lakes are net producers of nutrients, and face problems in disposing of them properly, particularly in concentrated animal facilities. Vineyards have not utilized compost extensively, and may benefit from the addition of organic matter, and by substituting compost applications for a portion of the vine's nitrogen needs. Increased microbial action could improve water infiltration into vineyard soils, and result in more even release and retention of nutrients.

The purpose of this study was to track changes in soil chemistry and vine productivity resulting from a single surface application of compost over a period of 3 growing seasons. We wanted to make one application and track the comparative vine performance and soil characteristics over several years in order to make practical recommendations to growers about the potential for compost use in vineyards.

RESEARCH DESIGN

The trial was set up at the Bill Dalrymple Farm on Upper Lake Road near Lodi, NY on the GR-7 grape variety. Plots for the trial were set up in a randomized complete block design with 4 replications and 4 treatments. Treatments consisted of:

- no nitrogen
- low rate of compost (5 tons /A)
- high rate of compost (12 tons/A)
- 30 lb/A of soil applied nitrogen (100 lb of ammonium nitrate)

Each plot consisted of six vines (3 vines per panel, 2 panels total) with vine spacing at 6 ft. and row spacing of 8 ft. Each replicate was in a separate, adjacent row. Compost was applied on June 6, 2003 in a 30 inch wide band evenly distributed under the trellis. Ammonium nitrate was applied on the same date in the same manner. In 2004 and 2005, standard ammonium nitrate (100 lb/acre, 30 lb actual nitrogen) was applied to the fertilizer plots. No additional compost was applied.

Soil samples were taken using a soil probe from four random areas under the trellis, 12" deep. Samples from each plot were combined and thoroughly mixed. Samples were collected at 2 week intervals, and tested for NO_3–N using a Card Nitrate tester. This provided seasonal trends for NO_3–N concentrations in the soil.

Plots were hand harvested on October 8, 2003. On September 23, 2004, a sample of clusters were harvested and weighed from each plot, and the number of clusters per vine was visually estimated. In 2005, plots were hand harvested on September 8. Harvest weight and cluster numbers were recorded for individual vines from 3 vines per plot. After weighing, 100 berries were collected from each vine, weighed, and crushed, yielding approximately 200 ml. juice for further analysis. Brix (juice soluble solids) was measured with a hand refractometer, and the remaining juice was frozen and retained for further analysis of basic juice chemistry (titratable acidity, malic and tartaric acid contents and pH.) at Thomas Henick-Kling's Enology lab at the NYS Agricultural Experiment Station in Geneva, NY.

RESULTS

Harvest Data

Tables 3-1 and 3-2 compare harvest data from 2003 through 2005. In 2005, there were no significant differences in berry weight, cluster weight, total crop yield, berries per cluster, cluster number or Brix between the treatments.

Table 3-1: Compost Trial Harvest Data (Cluster #, Cluster Weight and Vine Crop Weight).

Treatment	Cluster #			Cluster (lb)			Vine Crop Wt (lb)		
	2003	2004	2005	2003	2004	2005	2003	2004	2005
No Nitrogen	73	54	292	80.9	91.6	39.8	12.6	11.2	24.9
5T Compost	111*	66	288	87.6	104.1	38.2	21.8*	15.0	24.3
12T Compost	84	55	308	73.2	73.3	37.3	14.1	11.8	24.1
30 lb Nitrogen/Acre	104*	60	307	78.6	94.1	37.0	18.1	12.9	24.9

* Significantly different than control (No Nitrogen, no compost)

Table 3-2: Compost Trial Harvest Data (Berry Weight, Juice Soluble, Berries/Cluster).

Treatment	Berry Weight (g)			Juice Soluble			Berries per Cluster		
	2003	2004	2005	2003	2004	2005	2003	2004	2005
No Nitrogen	1.69	1.61	1.20	19.7	21.4	18.4	47.6	57.4	32.4
5T Compost	1.60	1.63	1.22	20.9	21.9	18.4	55.1	64.3	31.5
12T Compost	1.64	1.54	1.08	21.4	21.8	18.2	45.0	66.6	35.3
30 lb Nitrogen/Acre	1.63	1.64	1.15	19.5	21.1	17.9	48.4	57.5	32.0

* Significantly different than control (No Nitrogen, no compost)

Petiole Analysis

Petiole samples were collected in 2003 and 2004. For each sample, petioles were selected from a total of 30 leaves (last fully mature leaf from exposed shoots) from each plot. The samples were air dried and sent them to the Cornell Nutrient Analysis Laboratory for analysis. Table 3-3 shows the results. Major nutrient levels in grape petioles did not vary for any treatment.

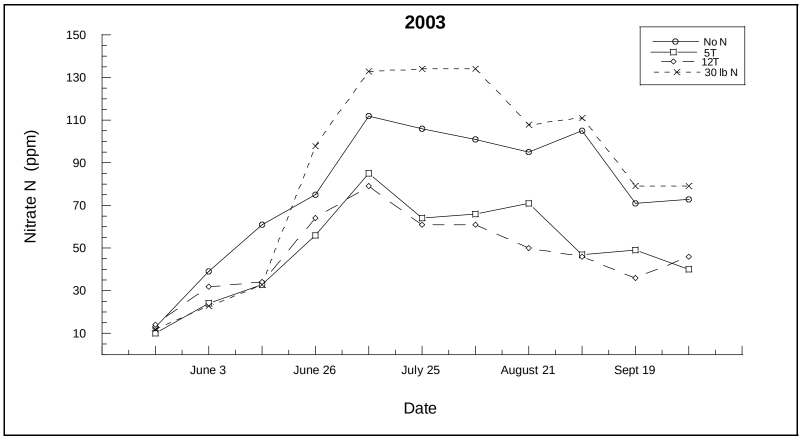
Table 3-3: Compost Trial Petiole Analysis.

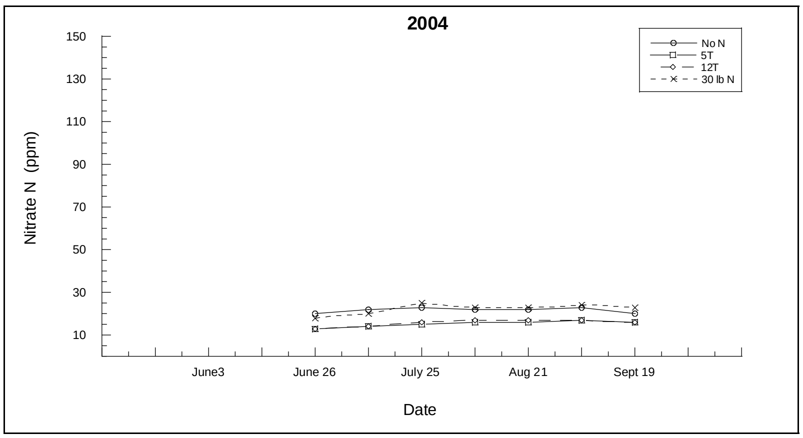
Treatment	Potassium (%)		Phosphorus (%)		Calcium (%)		Magnesium (ppm)	
	2003	2004	2003	2004	2003	2004	2003	2004
No Nitrogen	2.3	2.8	0.13	0.15	1.98	1.55	0.40	0.22
5T Compost	2.9	2.6	0.14	0.15	1.99	1.66	0.33	0.20
12T Compost	2.5	2.6	0.12	0.14	1.97	1.54	0.38	0.19
30 lb Nitrogen/Acre	2.7	3.1	0.14	0.17	1.92	1.59	0.32	0.18

* Significantly different than control (No Nitrogen, no compost)

PSNT Season data

The rapid PSNT test determines with a handheld Card Nitrate meter the concentration in ppm of nitrate-N in the soil. This form is readily taken up, and readily leaches through the soil. Table 3-4 shows the trends through the growing season. Figures 3-1 and 3-2 plot the seasonal trends. The trend continued in that free NO_3–N levels were lower in the two compost treatments than in either the zero or 30 lb actual N soil application but not significantly. The most plausible reason for this is that decomposition of the compost tied up some of the Nitrate-N, resulting in the lower levels.





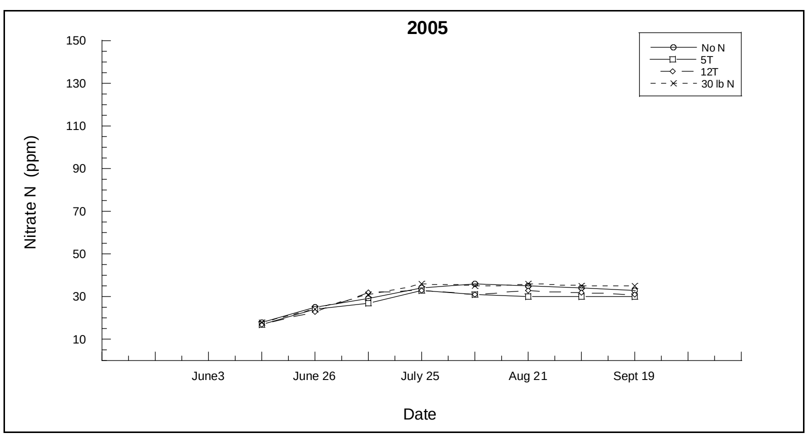
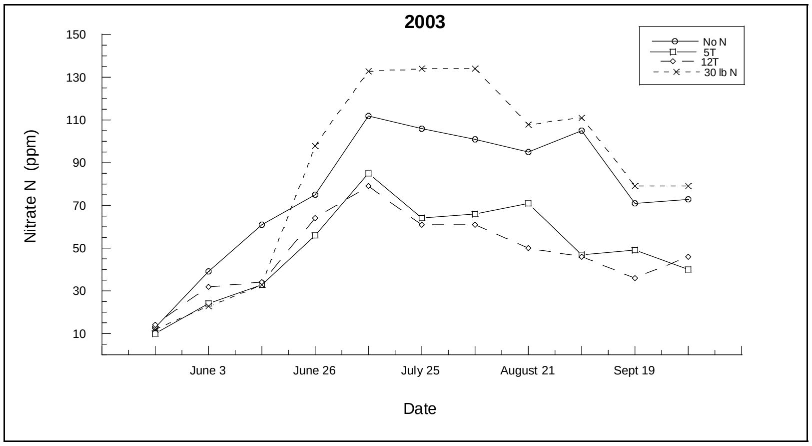
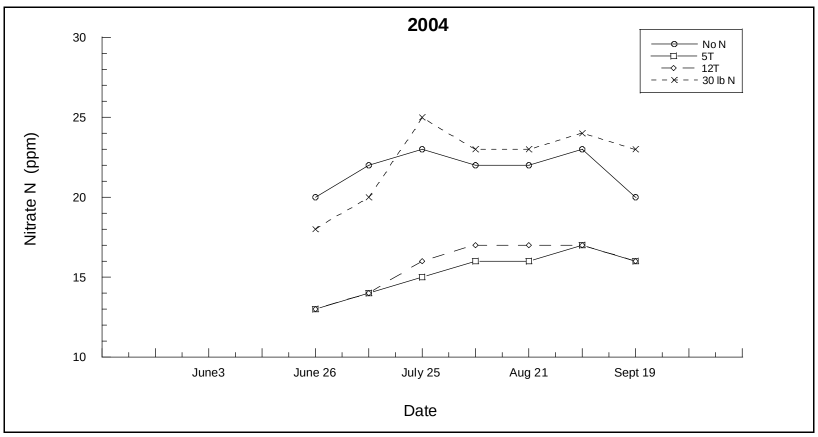


Figure 3-1: 2003 – 2005 Nitrate - Nitrogen Levels in Compost Trial (Same scale comparison).





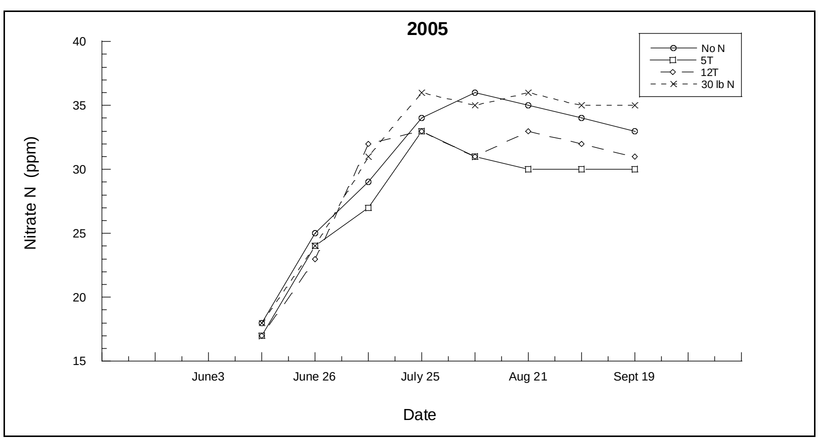


Figure 3-2: 2003 – 2005 Nitrate - Nitrogen Levels in Compost Trial.

Soil Analysis

Organic matter in 2003 was in the 3-5% range for all the soils (Table 3-4), which is variable but in the range one might want in a soil. Most interesting however is a comparison of the May and October soil tests with respect to nitrate levels. In the zero and 30 lb N fertilizer treatment, NO_3–N levels doubled, but in the two compost treatments, levels either stayed the same or decreased.

Table 3-4: Compost Trial Soil Analysis.

	Organic Matter (lb/A)		NO_3 – N (lb/A)		K (lb/A)		Mg (lb/A)		Ca (lb/A)	
Treatment	May	October	May	October	May	October	May	October	May	October
No N	4.4	4.6	52.4	91.2	487.0	448.5	200.2	201.7	1636.9	1620.1
5T Compost	5.1	5.2	45.6	58.7	443.6	455.7	214.7	207.5	1994.9	1971.9
12T Compost	3.4	3.7	53.4	29.2	416.6	461.9	150.2	127.3	1324.5	1118.6
30 Lb. N/A	5.0	5.1	42.2	101.8	400.0	524.0	201.8	180.6	1832.1	1682.5

* Significantly different than control (No Nitrogen, no compost)

Pruning Weights

Pruning weights reveal any gross differences in vine growth, which is related both to crop and to nitrogen availability. January 10 – 12, 2004, all vines were similarly pruned down to four main canes with about 30 buds per vine. Cuttings from all vines were collected and pruning weights recorded and analyzed. There were no significant differences between treatments (Table 3-5).

Table 3-5: Compost Trial Pruning Weight Analysis.

Treatment	Treatment Means (SEM)
No Nitrogen	0.90
5T/A Compost	1.27
12T/A Compost	0.99
30 Lb. N/A (actual N)	1.14

* Significantly different than control (No Nitrogen, no compost)

APPENDIX A

RESULTS OF SURVEY OF TURFGRASS INDUSTRY ON COMPOST USE

INTRODUCTION

In an effort to identify the current knowledge regarding compost use and the industry-specific goals and concerns in regard to compost use, a questionnaire was posted on the worldwide web and made available through workshops and meetings throughout the state. This questionnaire was created to identify compost use and knowledge by the turfgrass industry for both establishment and maintenance of turf and landscape plantings.

DEMOGRAPHICS

One hundred and eleven surveys were returned encompassing 61 “establishment” and 50 “maintenance”. The survey encompassed approximately 21 NY counties with 38% of the establishment and 44% of the maintenance surveys coming from Erie and Monroe Counties. Figure A-1 shows the settings where turf is established or maintained. Lawns, estates and cemeteries comprised 41% of the surveys for maintenance of turf, and athletic fields comprised 40%. “Athletic fields” includes both school and community fields (in parks). The “parks” category was parks that did not indicate having athletic fields. Other includes gardens, golf courses and nurseries, as well as 2 surveys with no answer for this question.

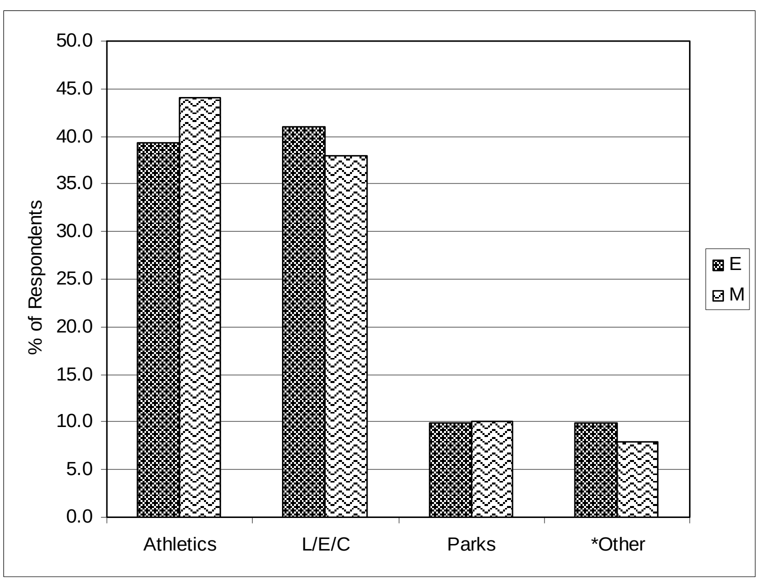


Figure A-1: Settings Where Turf is Established or Maintained

COMPOST USE

Respondents were asked "What are your experiences using compost?" The results are shown in Figure A-2. Compost was used occasionally by 38% and routinely by 31% of respondents responsible for establishment of turf. Turf maintenance respondents indicated less routine use (24%) and 41% used compost occasionally. Other responses included "we used to but had to stop due to weed problems", once, some at home and we use shredded hardwood.

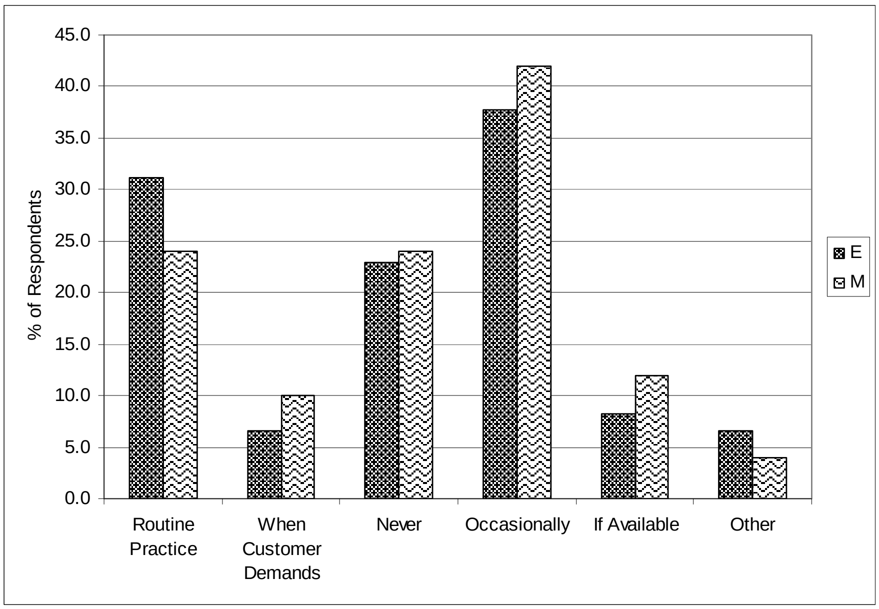


Figure A-2: Use of Compost by Establishment (n=61) and Maintenance (n=50)

Of the 19 establishment surveys that indicated compost use was routine practice, 42% used it on athletic fields and 42% on lawns, estates and cemeteries. For maintenance surveys (12 indicated routine use), 33% was on athletic fields and 58% was on lawns, estates and cemeteries (Figure A-3). However, there were just as many "never use" as routine use (Figure A-4).

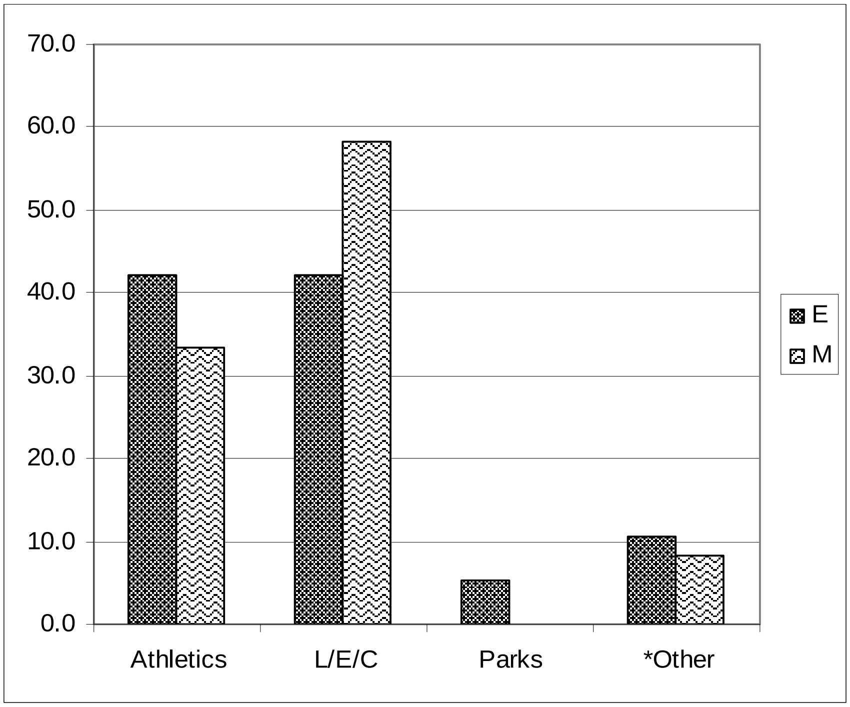


Figure A-3: Settings Where Compost Use is "Routine Practice" for Establishment (n= 19) and Maintenance (n=12).

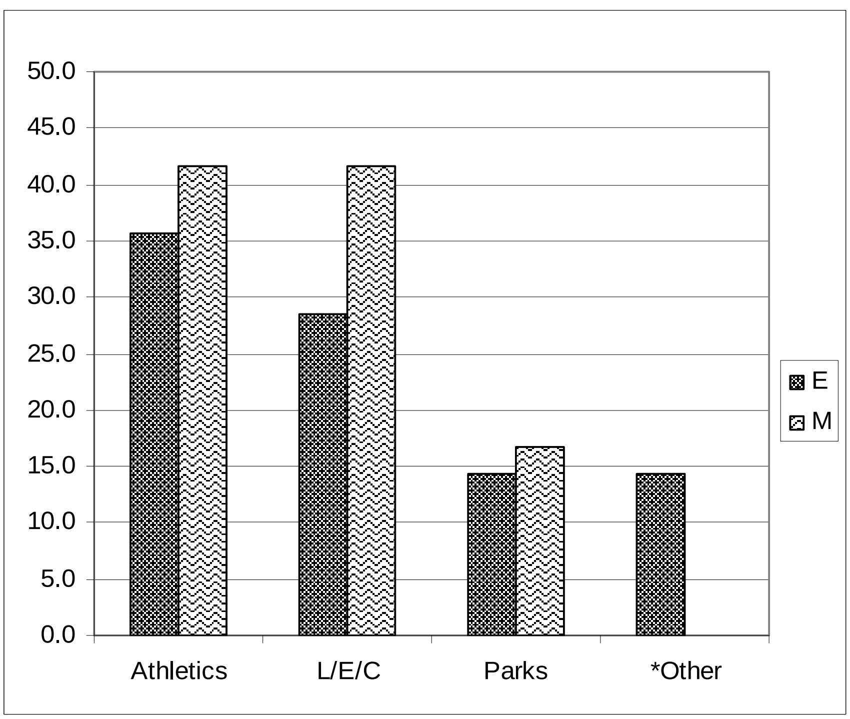


Figure A-4: Settings Where Compost Use is "Never" for Establishment (n=14) and Maintenance (n=12).

Some of the comments on the surveys regarding experience using compost are as follows:

- Routine practice: fill in low areas, top-dress twice per year, use at ¼” or ½” rates/1000 sq. ft.
- Never: would like to establish one (compost pile) for several reasons.
- Occasionally: when need help in sand, replace soil where salt effects.

Type of compost used is illustrated in Figure A-5. By far, leaf and yard waste was the most often used compost (76% Establishment and 63% Maintenance). Where respondents indicated “other” compost, they indicated specially mixed, peat, Nutribrew, municipal, horse manure, greenhouse, clippings/cores, brewery waste and bark. There did not seem to be any difference in type of compost used by setting (i.e. athletic fields vs lawns vs parks).

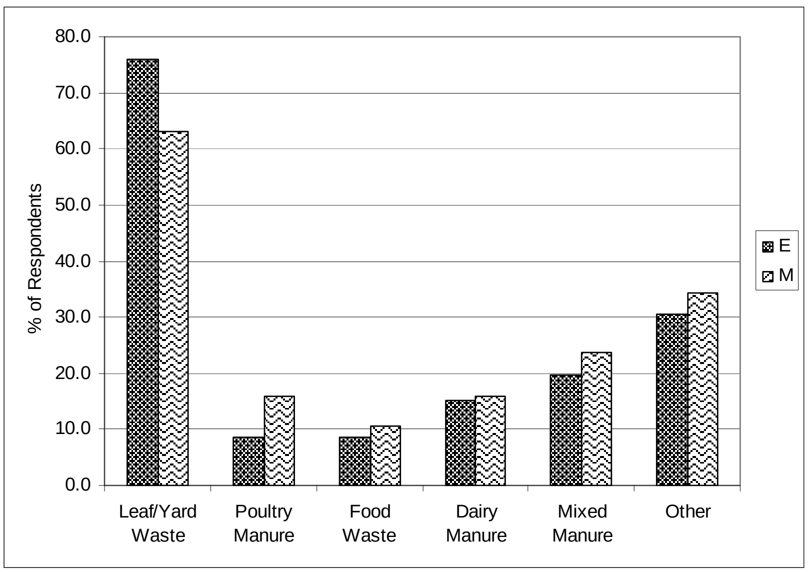


Figure A-5: Type of Compost Used by Establishment (n=61) and Maintenance (n=50).

Figure A-6 shows the concerns respondents have about using compost. The most common concern (59%) was weed seeds, followed by pH (43%). Compost users were more concerned about particle size (24% establishment, 28% maintenance) and inconsistency from batch to batch (39% establishment, 40% maintenance) than non-users (7% establishment, 17% maintenance and 27% establishment, 25% maintenance respectively). Other included sticky batches, clogs machines, public reaction, clean up, odor from manures and don't know enough to use.

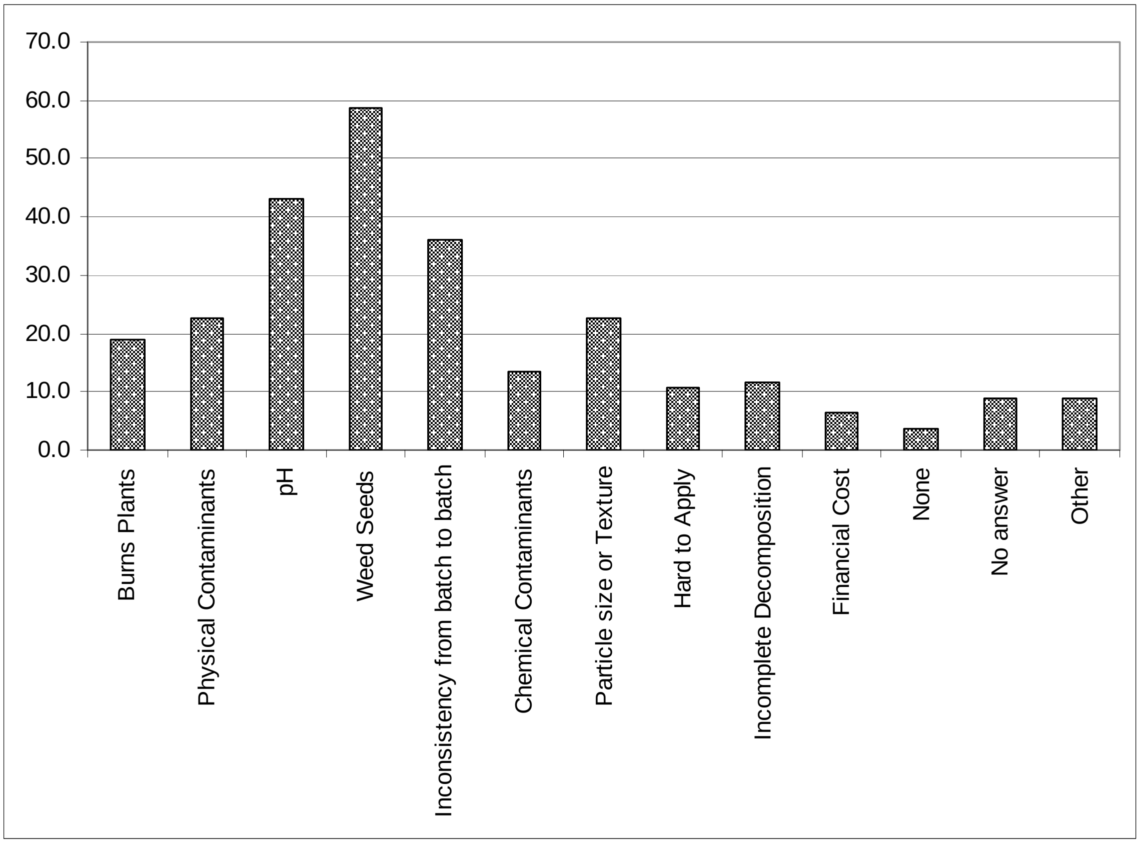


Figure A-6: Concerns About Using Compost (n=111).

The benefits expected from using compost were basically the same between users and non-users. Figure A-7 shows the benefits expected from all those surveyed. Improved soil structure and improved soil nutrient content were the most often sited benefits expected from using compost. Eighty-nine percent of users and 53% of non-users in turf establishment and 87 and 58% respectively in turf maintenance expected improved soil structure. Improved soil nutrient content was 85, 60, 74 and 67% respectively. Users were more likely to expect moisture retention/distribution than non-users (72% establishment, 66% maintenance users vs. 33% establishment, 25% maintenance non-users). All other benefits were about the same.

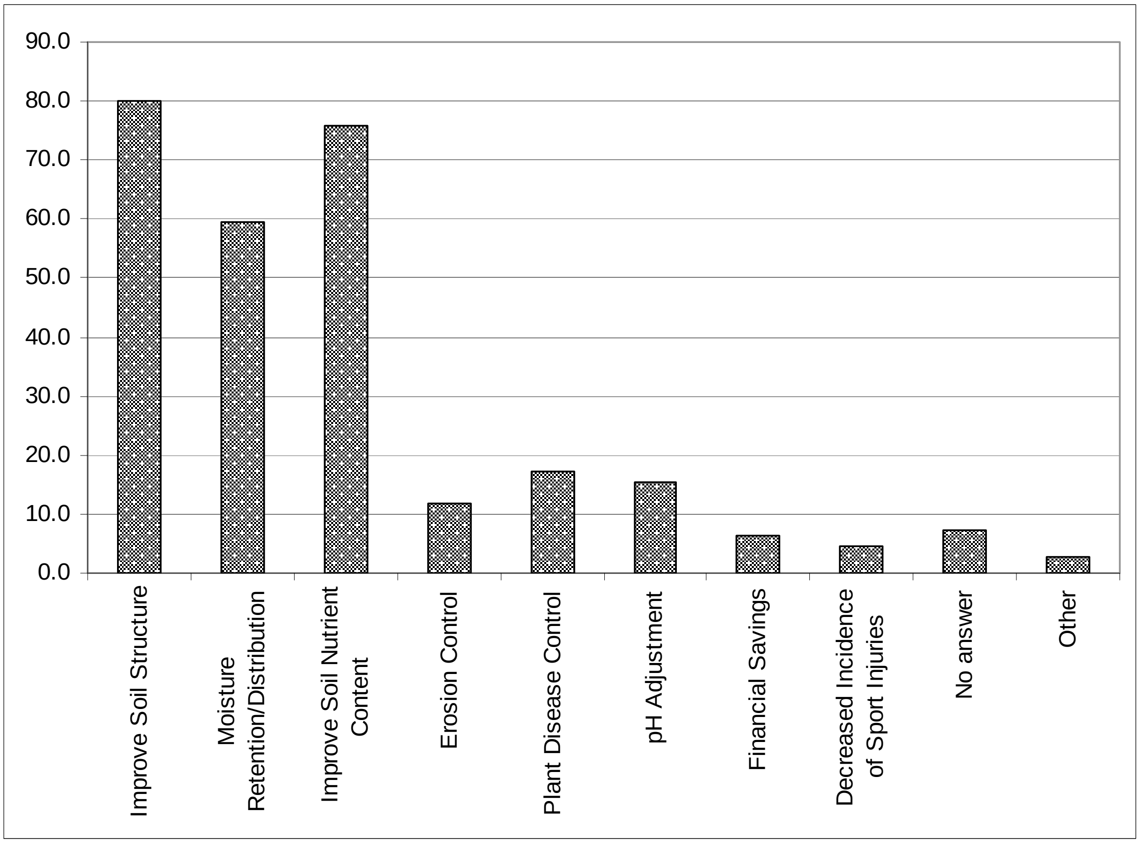


Figure A-7: Benefits From Using Compost (n=111).

When respondents were asked if they knew where to get compost, 76% of users and 60% of non-users (both establishment and maintenance n=111) said they did. However, 21% of the users (both establishment and maintenance n=84) said they were not able to get compost when they wanted it. Of the 84 users above, 29% indicated that they requested an analysis from their supplier.

The answers to what information about compost and compost use would help you decide whether or not to use compost were quite varied, but were able to be broken down into the following categories: availability, benefits/advantages, compost make-up, cost/cost effectiveness, general comment, general information, how to use, sources, standards/specifications and storing compost. Users and non-users alike were interested in the compost make-up (i.e. weed seeds, pH, nutrient analysis, how it's mixed and with what, how old it is and presence of salts/contaminants). Non-users were more interested in finding out the benefits/advantages of compost than users. These included: nutritional benefits, erosion control and improved soil properties. One respondent commented, "It's nice to know if you're benefiting your soils with what you're doing. We're putting a lot of material down using a lot of time and money. It's hard to justify the use sometimes. Users were more interested in availability, sources and some type of standards or specifications for using compost.

General information wanted included:

- Non-user: basically, is it going to be a good idea for our particular situation?
- User: all the basics and any information would be helpful

General comments were:

- We don't use, but intend to
- From experience, found there is a benefit, i.e. on clay soils
- I'm already sold on its uses in landscape plantings and new lawn establishment
- Mixed manure and yard waste at 2 to 1 ratio works best for turf grass
- Proper soil analysis would better determine need for compost use

MANAGEMENT PRACTICES

Respondents involved in establishment of turf were asked what amendments do you specify or use in establishing new turf and/or landscape plantings. Topsoil was used by 54% of those who used amendments and 48 and 42% used compost and peat respectively. Thirty-seven percent of those involved in establishing turf indicated that they used soil amendment specifications for turf or landscape plantings. The most common specification (59%) was pH, followed by NPK (54%). Percent organic matter and screened were both specifications used by 36% of those requiring specs.

Respondents involved in maintenance of turf were asked if they used fertilizers (both inorganic and organic). Forty-six percent of respondents did not use any inorganic fertilizer and 80% did not use any organic. Twenty surveys answered the question to describe any particular maintenance challenges (Figure A-8). The most common challenge was in scheduling: "it's hard to get products down at the proper times with students and excessive use", "accommodating lacrosse, field hockey and soccer all at once." Turf properties and resources were the second most common challenge.

Turf Properties:

- Our fields are overused and were built on lousy soil.
- Compaction
- Goal arches on multipurpose fields
- Keeping the turf from thinning out
- Very compacted areas/wet areas

Resources:

- Money for equipment and materials to properly care for the site

- Our athletic fields have received little or no organic amendments over the last 5 years, mostly because of the cost of material. It's a challenge to maintain these fields to a high level without the necessary tools.
- Not enough manpower, money or supplies to accomplish tasks needed to provide quality turf

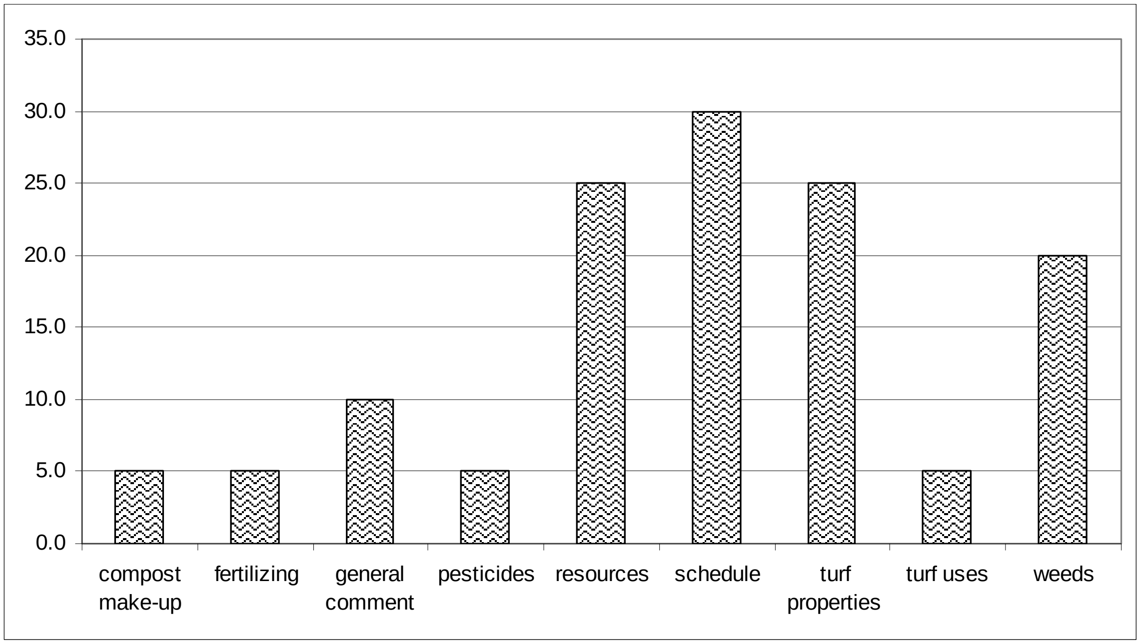


Figure A-8: Maintenance Challenges (n=20)

Both establishment and maintenance were asked if they tested the soils. Over 50% of both indicated they tested their soils for pH and complete nutrient analysis. Other testing included % organic matter, NPK and cation exchange capacity.

COMMUNICATION

Respondents were asked what the best way was to get information to them. Sixty percent indicated that meetings, workshops and field days were a great way to get information out. Specific ones mentioned were NYSTA conferences, local workshops and Cornell Field Days. Cooperative Extension was sited by 52% as a preferred vehicle and 48% indicated the use of trade publications. Specific publications were Sports Turf Publication, Landscape Management, Nursery Lines, Branching Out, Arborist News, ISA Journal, CUTT and Cornell Recommends.

APPENDIX B

NTEP TURFGRASS EVALUATION GUIDELINES

Prepared by:

Kevin N. Morris, Executive Director and Robert C. Shearman, Special Projects Coordinator

Introduction

The National Turfgrass Evaluation Program (NTEP) is a leader in evaluation of turfgrass species. The turfgrass industry in the USA and many parts of the world rely heavily on NTEP data. The information collected and summarized by NTEP is currently requested in thirty countries. Turfgrass breeders, researchers, and extension specialists use NTEP data to determine adaptation and use of cultivars and experimental lines. Seed companies rely on this data for advertisement and sales. Government agencies, like highway and parks departments, use NTEP data when writing specifications for bids and purchasing. Most importantly, end-users, like golf course superintendents, sports turf managers, sod growers, lawn care service operators, and grounds managers, frequently use the data before purchasing seed or sod. It is the interest of all of these users that has made NTEP data the standard for the turfgrass industry in the USA. The quality and scientific merit of NTEP data is extremely important. However, the evaluation of turfgrass species and cultivars is a difficult and complex issue. Furthermore, turfgrass evaluation is generally a subjective process based on visual estimates of factors, like genetic color, stand density, leaf texture, uniformity and quality. These factors can not be measured in the same way as other agricultural crops. Turfgrass quality is not a measure of yield or nutritive value. Turfgrass quality is a measure of aesthetics (i.e. density, uniformity, texture, smoothness, growth habit and color), and functional use. The most common way of assessing turfgrass quality is a visual rating system that is based on the turfgrass evaluator's judgement. Subjective measures of this type are always subject to criticism and concern. However, it is a well-established fact that properly trained observers can effectively discern subtle differences between turfgrasses, using the visual rating system. It is the overall goal of this document to provide guidance in the use of proper procedures and criteria for turfgrass evaluation. It is hoped that new turfgrass scientists will develop their evaluation skills, and that more senior scientists will hone their turfgrass evaluation capabilities.

Things to Consider

Visual ratings require consistency to ensure their merit. One person should take the data for a study. Avoid changing the person collecting visual ratings during the course of a growing season. Ideally, the same person should collect the visual ratings until the study is terminated. Keep a photographic record of treatment differences. Photos or slides are helpful in tracking treatment differences. Before taking data, observe the study. Do you see visual differences in color, density, uniformity, disease incidence, environmental stress or other factors? If so, your visual ratings should reflect these differences. Walk around the treatments. Identify the range of differences that you see. What are the best and worst treatments? What treatments are in the middle of the range? You may wish to mark these plots to use as a reference. You can refer back to them as you rate the study, keeping your ratings as consistent as possible. This process allows you to establish your rating range for each time that you rate the treatments. Visual ratings are based on a 1 to 9 rating scale. One is the poorest or lowest and 9 is the best or highest rating. Use as much of the rating scale as is reasonable and feasible. Base your range on the overall differences that you observe. It is important that you do not compress the rating scale. Rate only in whole numbers. It is ideal to conduct visual evaluations on cloud-covered days, when shadows and reflections are minimal. Take data between midmorning to early afternoon, when the sun is at its highest. Keep the sun at your back. Avoid recording visual ratings on partially cloudy days. The intermittent cover causes sun flecks, and periods of brightness and shadows, making it difficult to evaluate treatment differences. It is best to have some one record data or use a data recorder. This approach speeds up the data collection and reduces glare resulting from glancing back and forth between paper and green verdure. With some characteristics, like genetic color, differences are more evident prior to mowing. Mowing direction causes difference in light reflection and may influence color ratings. If the turf is mowed prior to rating, it is best to mow replications in the same direction. This will minimize reflection differences.

Turfgrass Quality

Quality is based on 9 being best and 1 being poorest. A rating of 6 or above is generally considered acceptable. A quality rating value of 9 is reserved for a perfect or ideal grass, but it also can reflect an absolutely outstanding treatment plot. The NTEP requires quality ratings on a monthly basis. Quality ratings will vary based on turfgrass species, intensity of management and time of year. Within species quality ratings are relative. Among species they are not. For example an acceptable quality rating of 6 within tall fescue cultivars is not relative to the same value given among Kentucky bluegrasses. An acceptable quality rating value for a utility turf differs from the same value for a bentgrass putting green. Quality ratings take into account the aesthetic and functional aspects of the turf. Quality ratings are not based on color alone, but on a combination of color, density, uniformity, texture, and disease or environmental stress. Turfs growing in a study may receive the same numeric quality rating, but the factors influencing that rating may differ. For example, one turf may receive a quality rating value of 5 based on overall color and density, while another may receive the same value based on disease incidence and its impact on turfgrass density. It is important to keep these facts in mind, when rating turfgrass quality. It is also important to keep this in mind when interpreting data from various studies.

Genetic Color

Genetic color reflects the inherent color of the genotype. It is based on a visual rating scale with 1 being light green and 9 being dark green. Take genetic color ratings when the turf is actively growing and is not under stress. Chlorosis and browning from necrosis are not a part of genetic color. Color charts, like those sold by the Munsell Color Company, Inc., are helpful in describing turfgrass color and serve as a reference. Color charts are useful in maintaining consistent visual color ratings.

Turfgrass Density

Turfgrass density is a visual estimate of living plants or tillers per unit area. Dead patches of turf are excluded. A visual rating of 1 to 9 is used with 9 equaling maximum density. Turfgrass density can be determined quantitatively by counting shoots in a specified area. Counting is time consuming and labor intensive. Visual turfgrass density ratings are highly correlated to counts and require much less time and labor input. Shoot density varies by time of year. It is best to take density ratings in the spring, summer, and fall to account for seasonal variation. This is particularly true for cool-season turfgrasses.

Percent Living Ground Cover

Percent living ground cover is based on surface area covered by the originally planted species. It is generally used to express damage caused by disease, insects, weed encroachment, or environmental stress. Percent living ground cover is often measured in the spring, summer, and fall. This timing allows one to track the turfgrass response to various stresses during the growing season.

Turfgrass Texture

Turfgrass texture is a measure or estimate of leaf width. The visual rating of texture is based on a 1 to 9 rating scale with 1 equaling coarse and 9 equaling fine. Visual assessment of texture is difficult and less than precise. However, physical measurement is tedious, time consuming and labor intensive. Physical measurements are also variable. Care must be taken to measure leafs of similar age and stage of development. Visual ratings of texture can be used successfully to separate cultivars within species. Visual assessment of leaf texture should be done when the turfgrass is actively growing and is not under stress.

Other Color Data

Spring Green-up

Green-up is a measure of the transition from winter dormancy to active spring growth. It is based on plot color not genetic color. The visual rating of spring green-up is based on a 1 to 9 rating scale with 1 being straw brown and 9 being dark green.

Winter Color

An assessment of color retention during the winter months. It is based on a 1 to 9 visual rating scale with 1 equaling straw brown or no color retention, and 9 equaling dark green. It assesses overall plot color and not genetic color.

Seasonal Color/Color Retention

Seasonal color and color retention ratings are a measure of overall plot color. The scale used is 1 to 9 scale with 1 being straw brown and 9 being dark green. Seasonal color can be used to successfully differentiate color differences based on damage caused by disease or insect pests, nutrient deficiency or environmental stress. Color retention is used to assess the ability of the entry to hold color as seasons change. This is especially useful in quantifying the response of warm-season grasses to temperature changes or frost occurring in fall.

Other Data

Pest Problems

Pests include disease, insects and weeds. The NTEP reports disease and insect injury based on the turfgrass resistance, using the 1 to 9 rating scale with 1 equaling no resistance or 100% injury, and 9 equaling complete resistance or no injury. Insect incidence may also be determined as counts per unit area. Always identify disease and insects to genus and species. Verify the genus and species through the appropriate specialist (i.e. plant pathologist, entomologist, etc.). Weed infestation or encroachment is generally expressed as percent ground cover. Weeds should be identified to genus and species.

Environmental Stress

Stresses, like drought and winter injury, cause severe turfgrass damage. Turfgrass cultivars differ in their ability to tolerate and recover from these stresses.

Drought Stress

Drought stress resistance is assessed as wilting, leaf firing, dormancy, and recovery. A 1 to 9 visual rating scale is used with 1 being complete wilting, 100% leaf firing, complete dormancy or no plant recovery; and 9 being no wilting, no leaf firing, 100% green-no dormancy, or 100% recovery.

Winter Injury

Freezing or direct low temperature, desiccation, and frost injury can comprise winter injury symptoms. It is important to identify the cause of the winter injury symptoms. Turfgrass species and cultivars differ in their responses to each of these stresses. Direct low temperature and desiccation injury are generally expressed as a visual estimate of percent damaged ground cover. Frost injury is expressed on a 1 to 9 rating scale with 1 equaling 100% leaf injury and 9 equaling no injury.

Traffic Tolerance

Traffic tolerance is the combination of wear and compaction stress that occurs whenever a turf is exposed to foot or vehicular traffic. Wear injury occurs immediately upon trafficking a turf. Wear injury symptoms are often expressed within hours and definitely within days. Compaction stress injury is more chronic. It is expressed over time. The NTEP reports traffic tolerance as visual estimate of turfgrass tolerance using a 1 to 9 rating scale with 1 being no tolerance or 100% injury, and 9 being complete tolerance or no injury.

Thatch Accumulation

Thatch is generally a measured value. Compressed thatch depth is preferred. It gives values with reduced variability. Collect 4, 5-cm plugs of turf-, remove the verdure; place a 1 kg weight on the surface of the thatch; and measure the compressed thatch depth in mm. Thatch accumulation measurements are time consuming and labor intensive.

APPENDIX C

STATISTICAL ANALYSIS OF TURFGRASS DATA

STATISTICAL ANALYSIS DESCRIPTION

Statistical analysis of soil chemical properties (phosphorus, manganese, iron, pH and organic matter), soil physical properties (bulk density, and aggregate stability), turf quality data (% grass, % weeds, % bare and overall turfgrass quality rating), and infiltration data collected at Clarence (site 1 – loam), Minisink (site 2 – sandy loam), Rochester (site 3 – very fine sandy loam) and Pine Island (site 4 – coarse sandy loam) were analyzed using the S-Plus statistical package. Each site was analyzed separately. Changes over time for each treatment were analyzed by linear regression and subsequent analysis of variance of the linear regression. The results are provided in the tables below. Treatment differences at each sampling were analyzed using analysis of variance (ANOVA) for multiple comparisons with Tukey corrections. Statistical analysis of the difference between the treatment means was conducted only for those treatments where the analysis of variance indicated a difference and the tables below show only those dates and sites where there were treatment differences. All data was observed for normality prior to analysis using a normal quartile plot. When data in its raw state was not fairly normal, a log 10 transformation of the response variable (i.e. soil property) was made and those numbers were used for analysis.

SOIL CHEMICAL PROPERTIES

The soil chemical properties that were analyzed were phosphorus, manganese, iron, pH and organic matter. Analysis was done by the Cornell Nutrient Analysis Laboratory, Bradfield Hall, Ithaca, NY. Table A-1 shows the values used for data analysis of soil chemical properties at each site. Phosphorus, manganese and iron needed to be transformed for the Clarence data analysis, phosphorus at Rochester, and Iron at Pine Island. All other variables were analyzed using the raw data.

Table C-1: Values Used for Data Analysis of Soil Chemical Properties at Each Site.

Site	pH	Manganese	Iron	Phosphorus	Organic Matter
Clarence	Raw data	Log 10	Log 10	Log 10	Raw data
Minisink	Raw data	Raw data	Raw data	Raw data	Raw data
Rochester	Raw data	Raw data	Raw data	Log 10	Raw data
Pine Island	Raw data	Raw data	Log 10	Raw data	Raw data

Statistical Analysis Results for pH

Table C-2: Linear Regression Results by Treatment Over Time for Soil pH

Site	Treatment	Regression Line	p-Value	Multiple R^2
Clarence	¼” Poultry		Not significant	
	½” Poultry		Not significant	
	¼” Dairy		Not significant	
	½” Dairy		Not significant	
	Fertilizer, No Compost		Not significant	
	No Fertilizer, No Compost		Not significant	
Minisink	¼” Poultry	y = 6.62 + 0.02x	0.0007	0.6040
	½” Poultry	y = 6.56 + 0.03x	0.0004	0.6355
	¼” Dairy	y = 6.47 + 0.02x	0.0002	0.6755
	½” Dairy	y = 6.51 + 0.02x	0.0013	0.5632
	Fertilizer, No Compost	y = 6.42 + 0.01x	0.0226	0.3397
	No Fertilizer, No Compost	y = 6.37 + 0.02x	0.0011	0.5715
Rochester	¼” Poultry		Not significant	
	½” Poultry		Not significant	
	¼” Dairy		Not significant	
	½” Dairy		Not significant	
	Fertilizer, No Compost		Not significant	
	No Fertilizer, No Compost		Not significant	
Pine Island	¼” Poultry	y = 6.54 + 0.03x	0.0027	0.5128
	½” Poultry	y = 6.35 + 0.04x	0.0012	0.5661
	¼” Dairy		Not significant	
	½” Dairy	y = 6.31 + 0.03x	0.0036	0.4912
	Fertilizer, No Compost		Not significant	
	No Fertilizer, No Compost		Not significant	

Table C-3: Mean Soil pH Levels at Sampling Dates Showing Significant Differences Between Treatments at Each site. Values followed by different superscripts in each column are significantly different ($p < 0.05$).

Site	Minisink				Rochester	Pine Island	
Date	9/04	6/05	9/05	7/06	6/06	6/05	9/05
¼” P	7.18[a]	6.99[ab]	7.18[a]	7.23[a]	7.56[ab]	7.37[a]	7.18[a]
½” P	7.27[a]	7.03[a]	7.22[a]	7.34[a]	7.67[ab]	7.42[a]	7.28[a]
¼” D	6.85[b]	6.73[bc]	6.82[b]	6.96[b]	7.55[ab]	7.08[ab]	6.77[ab]
½” D	6.93[b]	6.70[bc]	6.90[b]	6.96[b]	7.56[a]	7.16[ab]	6.81[ab]
F NC	6.78[b]	6.54[c]	6.54[c]	6.79[b]	7.72[ab]	6.71[b]	6.40[b]
NF NC	6.76[b]	6.57[c]	6.68[bc]	6.88[b]	7.70[b]	6.84[b]	6.57[b]

Statistical Analysis Results for Manganese

Table C-4: Linear Regression Results by Treatment Over Time for Soil Manganese.

Site	Treatment	Regression Line	p-Value	Multiple R^2
Clarence	¼” Poultry		Not significant	
	½” Poultry	y = 17.67 + 1.02x	0.0000	0.7859
	¼” Dairy		Not significant	
	½” Dairy		Not significant	
	Fertilizer, No Compost		Not significant	
	No Fertilizer, No Compost		Not significant	
Minisink	¼” Poultry	y = 26.70 + 0.52x	0.0194	0.3536
	½” Poultry	y = 31.43 + 0.73x	0.0154	0.3738
	¼” Dairy		Not significant	
	½” Dairy		Not significant	
	Fertilizer, No Compost		Not significant	
	No Fertilizer, No Compost		Not significant	
Rochester	¼” Poultry		Not significant	
	½” Poultry	y = 28.99 + 0.70x	0.0252	0.3298
	¼” Dairy		Not significant	
	½” Dairy		Not significant	
	Fertilizer, No Compost		Not significant	
	No Fertilizer, No Compost		Not significant	
Pine Island	¼” Poultry	y = 30.61 + 0.67x	0.0038	0.4879
	½” Poultry	y = 33.29 + 1.08x	0.0032	0.4994

	¼” Dairy		Not significant	
	½” Dairy		Not significant	
	Fertilizer, No Compost		Not significant	
	No Fertilizer, No Compost		Not significant	

Table C-5: Mean Soil Manganese Levels at Sampling Dates Showing Significant Differences Between Treatments at Each Site. Values followed by different superscripts in each column are significantly different ($p < 0.05$).

Site	Clarence	Minisink				Rochester				Pine Island			
Date	6/06	9/04	6/05	9/05	7/06	9/04	6/05	11/05	6/06	9/04	6/05	9/05	6/06
¼” P	20.9^{ac}	44.6^{ab}	38.2^{a}	34.6^{a}	42.4^{ab}	35.8^{ab}	28.4^{a}	35.1^{ab}	24.7^{a}	46.3^{ab}	53.3^{a}	44.3^{a}	45.9^{a}
½” P	38.0^{b}	56.2^{b}	48.4^{a}	48.1^{b}	49.2^{a}	50.6^{a}	52.1^{b}	44.7^{b}	42.7^{b}	59.3^{a}	64.1^{a}	63.1^{a}	55.9^{a}
¼” D	17.3^{ac}	29.1^{c}	17.9^{b}	18.1^{c}	22.3^{c}	32.2^{ab}	25.1^{a}	29.4^{a}	16.7^{a}	27.0^{bc}	20.4^{b}	18.6^{b}	25.5^{b}
½” D	22.6^{a}	31.5^{c}	20.9^{b}	22.8^{c}	24.6^{c}	33.9^{ab}	27.4^{a}	35.3^{ab}	23.0^{a}	24.3^{c}	24.7^{b}	19.7^{b}	24.5^{b}
F NC	16.5^{ac}	32.0^{bc}	18.4^{b}	18.4^{c}	23.5^{c}	24.8^{b}	22.3^{a}	27.9^{a}	15.9^{a}	27.0^{bc}	20.1^{b}	20.8^{b}	25.8^{b}
NF NC	13.7^{c}	32.6^{bc}	18.9^{b}	17.7^{c}	30.6^{bc}	31.0^{b}	25.0^{a}	31.9^{a}	19.6^{a}	27.0^{bc}	17.9^{b}	15.8^{b}	25.6^{b}

Statistical Analysis Results for Iron

Table C-6: Linear Regression Results by Treatment Over Time for Soil Iron.

Site	Treatment	Regression Line	p-Value	Multiple R^2
Clarence	¼” Poultry		Not significant	
	½” Poultry		Not significant	
	¼” Dairy		Not significant	
	½” Dairy		Not significant	
	Fertilizer, No Compost		Not significant	
	No Fertilizer, No Compost		Not significant	
Minisink	¼” Poultry		Not significant	
	½” Poultry		Not significant	
	¼” Dairy		Not significant	
	½” Dairy		Not significant	
	Fertilizer, No Compost		Not significant	
	No Fertilizer, No Compost	$y = 3.19 – 0.05x$	0.0114	0.3997
Rochester	¼” Poultry	$y = 4.93 – 0.05x$	0.0102	0.4095
	½” Poultry		Not significant	
	¼” Dairy		Not significant	
	½” Dairy	$y = 3.70 + 0.07x$	0.0376	0.2919
	Fertilizer, No Compost		Not significant	

	No Fertilizer, No Compost		Not significant	
Pine Island	¼" Poultry		Not significant	
	½" Poultry	y = 0.00 + 0.01x	0.0115	0.3996
	¼" Dairy		Not significant	
	½" Dairy		Not significant	
	Fertilizer, No Compost		Not significant	
	No Fertilizer, No Compost		Not significant	

Table C-7: Mean Soil Iron Levels at Sampling Dates Showing Significant Differences Between Treatments at Each Site. Values followed by different superscripts in each column are significantly different ($p < 0.05$).

Site	Clarence	Minisink	Rochester		Pine Island		
Date	6/06	9/04	9/04	11/05	9/04	6/05	9/05
¼" P	2.30^{ab}	2.42^{ab}	4.76^{ab}	3.99^{ab}	1.99^{a}	2.32^{a}	1.17^{ab}
½" P	1.67^{ab}	2.02^{a}	3.13^{a}	3.91^{a}	1.66^{ab}	1.30^{ab}	1.75^{a}
¼" D	2.20^{ab}	3.00^{ab}	5.08^{ab}	4.58^{ab}	1.40^{ab}	1.26^{ab}	0.96^{ab}
½" D	3.73^{a}	3.03^{b}	4.88^{ab}	5.87^{b}	1.79^{ab}	2.83^{a}	1.14^{ab}
F NC	1.90^{ab}	3.03^{b}	5.14^{ab}	5.66^{ab}	1.07^{ab}	0.62^{bc}	0.90^{ab}
NF NC	1.40^{b}	3.06^{b}	6.48^{b}	5.40^{ab}	0.96^{b}	0.39^{cd}	0.47^{b}

Statistical Analysis Results for Phosphorus

Table C-8: Linear Regression Results by Treatment Over Time for Soil Phosphorus.

Site	Treatment	Regression Line	p-Value for slope	Multiple R^2
Clarence	¼" Poultry	y = 4.66 + 1.11x	0.0001	0.7102
	½" Poultry	y = 10.62 + 1.10x	0.0026	0.5150
	¼" Dairy	y = 5.77 + 1.11x	0.0000	0.7344
	½" Dairy	y = 12.65 + 1.08x	0.0040	0.4830
	Fertilizer, No Compost		Not significant	
	No Fertilizer, No Compost		Not significant	
Minisink	¼" Poultry		Not significant	
	½" Poultry	y = 54.95 + 5.63x	0.0061	0.4518
	¼" Dairy	y = 37.53 + 4.41x	0.0000	0.7813
	½" Dairy	y = 36.50 + 4.15x	0.0391	0.2881
	Fertilizer, No Compost		Not significant	
	No Fertilizer, No Compost	y = 35.78 + 1.03x	0.0037	0.4884
Rochester	¼" Poultry	y = 12.58 + 1.08x	0.0024	0.5191

	½” Poultry	y = 18.21 + 1.09x	0.0024	0.5209
	¼” Dairy	y = 9.15 + 1.09x	0.0000	0.7984
	½” Dairy	y = 14.66 + 1.09x	0.0030	0.6395
	Fertilizer, No Compost		Not significant	
	No Fertilizer, No Compost		Not significant	
Pine Island	¼” Poultry	y = 37.37 + 4.68x	0.0158	0.3717
	½” Poultry	y = 48.99 + 5.37x	0.0054	0.4601
	¼” Dairy	y = 41.90 + 5.39x	0.0008	0.5896
	½” Dairy		Not significant	
	Fertilizer, No Compost		Not significant	
	No Fertilizer, No Compost	y = 19.75 + 0.64x	0.0382	0.2903

Table C-9: Mean Soil Phosphorus Levels at Sampling Dates Showing Significant Differences Between Treatments at Each Site. Values followed by different superscripts in each column are significantly different ($p < 0.05$).

Site	Clarence			Minisink		Rochester				Pine Island		
Date	9/04	9/05	6/06	9/04	7/06	9/04	6/05	11/05	6/06	9/04	6/05	6/06
¼” P	66.4^{ab}	44.0^{a}	164.6^{a}	223.4^{a}	194.9^{ab}	123.3^{ab}	42.4^{a}	38.7^{a}	179.7^{a}	171.4^{ab}	138.8^{a}	237.3^{a}
½” P	173.0^{a}	107.5^{a}	160.5^{a}	177.4^{a}	274.0^{a}	207.4^{a}	123.9^{b}	208.0^{b}	135.1^{a}	197.1^{a}	162.5^{a}	236.9^{a}
¼” D	39.0^{ab}	66.8^{a}	142.8^{a}	89.9^{b}	173.3^{ab}	44.9^{b}	65.9^{ab}	79.4^{ab}	86.7^{a}	93.3^{bc}	221.0^{b}	158.5^{a}
½” D	126.7^{a}	118.1^{a}	94.6^{a}	142.4^{ab}	228.5^{a}	76.5^{ab}	169.8^{b}	240.1^{b}	125.0^{a}	191.1^{a}	36.2^{c}	181.6^{a}
F NC	5.3^{b}	8.0^{b}	11.0^{b}	60.9^{b}	73.0^{b}	8.7^{c}	10.1^{c}	11.3^{c}	11.1^{b}	32.9^{c}	28.8^{c}	38.9^{b}
NF NC	5.4^{b}	6.0^{b}	9.0^{b}	59.4^{b}	68.3^{b}	10.0^{c}	6.8^{c}	9.1^{c}	9.5^{b}	36.3^{c}	33.3^{c}	38.1^{b}

<u>Statistical Analysis Results for Organic Matter</u>

Table C-10: Linear Regression Results by Treatment Over Time for Soil Organic Matter

Site	Treatment	Regression Line	p-Value	Multiple R^2
Clarence	¼” Poultry	y = 7.69 + 0.06x	0.0224	0.3404
	½” Poultry	y = 7.23 + 0.15x	0.0010	0.5756
	¼” Dairy		Not significant	
	½” Dairy	y = 7.88 + 0.11x	0.0016	0.5741
	Fertilizer, No Compost		Not significant	
	No Fertilizer, No Compost		Not significant	
Minisink	¼” Poultry	y = 7.98 + 0.21x	0.0047	0.4720
	½” Poultry	y = 9.06 + 0.29x	0.0001	0.6858
	¼” Dairy	y = 6.99 + 0.14x	0.0003	0.6521
	½” Dairy	y = 9.52 + 0.18x	0.0036	0.4922

	Fertilizer, No Compost		Not significant	
	No Fertilizer, No Compost		Not significant	
Rochester	¼" Poultry	y = 5.21 + 0.08x	0.0001	0.7186
	½" Poultry	y = 5.42 + 0.16x	0.0004	0.6351
	¼" Dairy	y = 5.16 + 0.07x	0.001	0.6848
	½" Dairy	y = 5.47 + 0.13x	0.0000	0.7752
	Fertilizer, No Compost		Not significant	
	No Fertilizer, No Compost		Not significant	
Pine Island	¼" Poultry	y = 5.06 + 0.26x	0.0001	0.6969
	½" Poultry	y = 5.93 + 0.37x	0.0000	0.7345
	¼" Dairy	y = 5.63 + 0.15x	0.0075	0.4350
	½" Dairy	y = 5.15 + 0.19x	0.0063	0.4486
	Fertilizer, No Compost		Not significant	
	No Fertilizer, No Compost		Not significant	

Table C-11: Mean Soil Organic Matter Levels at Sampling Dates Showing Significant Differences Between Treatments at Each Site. Values followed by different superscripts in each column are significantly different ($p < 0.05$).

Site	Clarence		Minisink		Rochester			Pine Island		
Date	9/05	6/06	9/05	7/06	6/05	11/05	6/06	6/05	9/05	6/06
¼" P	8.44^{ab}	9.65^{ac}	12.75^{a}	15.11^{ab}	7.39^{a}	6.36^{ac}	7.89^{abc}	13.69^{a}	10.72^{a}	12.05^{a}
½" P	9.90^{ab}	12.77^{b}	18.52^{b}	18.25^{a}	10.49^{b}	8.07^{b}	10.47^{a}	15.79^{a}	16.18^{b}	15.55^{b}
¼" D	9.01^{ab}	10.19^{ab}	11.47^{a}	11.96^{ab}	7.42^{a}	6.39^{a}	7.49^{bc}	11.05^{ab}	9.72^{ac}	8.46^{c}
½" D	11.17^{a}	11.05^{ab}	13.77^{ab}	15.29^{ab}	8.60^{c}	8.18^{b}	10.02^{ab}	11.96^{a}	8.08^{acd}	10.61^{ac}
F NC	7.40^{b}	7.62^{c}	10.39^{a}	10.01^{b}	6.07^{d}	5.19^{c}	5.68^{c}	5.89^{b}	6.33^{d}	5.52^{d}
NF NC	7.20^{b}	7.81^{c}	9.36^{a}	11.70^{ab}	5.68^{d}	5.10^{c}	5.49^{c}	5.74^{b}	5.96^{d}	5.21^{d}

SOIL PHYSICAL PROPERTIES

The soil physical properties that were analyzed were bulk density, and aggregate stability. Analysis was done by the Cornell Nutrient Analysis Laboratory, Cornell University, Ithaca, NY. All of the soil physical property variables were analyzed using the raw data.. Aggregate stability was added in June 2005, so there were no pretreatment values for this variable, therefore linear regression was not performed.

Statistical Analysis Results for Bulk Density

Table C-12: Linear Regression Results by Treatment Over Time for Soil Bulk Density

Site	Treatment	Regression Line	p-Value	Multiple R^2
Clarence	¼” Poultry	y = 1.34 - 0.013x	0.0000	0.7657
	½” Poultry	y = 1.33 - 0.014x	0.0000	0.8425
	¼” Dairy	y = 1.29 - 0.009x	0.0000	0.6797
	½” Dairy	y = 1.36 - 0.016x	0.0000	0.8793
	Fertilizer, No Compost	y = 1.33 - 0.008x	0.0000	0.5318
	No Fertilizer, No Compost	y = 1.32 - 0.004x	0.0000	0.4380
Minisink	¼” Poultry	y = 1.50 - 0.021x	0.0000	0.7913
	½” Poultry	y = 1.49 - 0.022x	0.0000	0.6919
	¼” Dairy	y = 1.49 - 0.016x	0.0000	0.5363
	½” Dairy	y = 1.41 - 0.021x	0.0000	0.6276
	Fertilizer, No Compost	y = 1.49 - 0.014x	0.0000	0.4955
	No Fertilizer, No Compost	y = 1.58 - 0.016x	0.0000	0.6919
Rochester	¼” Poultry	y = 1.41 - 0.016x	0.0000	0.8272
	½” Poultry	y = 1.48 - 0.024x	0.0000	0.8590
	¼” Dairy	y = 1.38 - 0.013x	0.0000	0.4166
	½” Dairy	y = 1.42 - 0.017x	0.0000	0.8365
	Fertilizer, No Compost		Not significant	
	No Fertilizer, No Compost	y = 1.46 - 0.008x	0.0000	0.3872
Pine Island	¼” Poultry	y = 1.42 - 0.014x	0.0000	0.2711
	½” Poultry		Not significant	
	¼” Dairy	y = 1.46 - 0.017x	0.0000	0.4149
	½” Dairy		Not significant	
	Fertilizer, No Compost		Not significant	
	No Fertilizer, No Compost	y = 1.56 - 0.013x	0.0000	0.3939

Table C-13: Mean Soil Bulk Density Levels at Sampling Dates Showing Significant Differences Between Treatments at Each Site. Values followed by different superscripts in each column are significantly different ($p < 0.05$)

Site	Clarence			Minisink	Rochester			Pine Island
Date	6/05	9/05	6/06	9/05	6/05	11/05	6/06	9/05
¼" P	1.09^{abc}	1.03^{ab}	0.90^{ab}	0.89^{abc}	1.00^{ab}	1.02^{abc}	0.93^{ab}	0.93^{a}
½" P	1.03^{ab}	0.94^{a}	0.86^{ab}	0.75^{a}	0.87^{a}	0.86^{a}	0.73^{a}	0.76^{a}
¼" D	1.07^{abc}	1.09^{bc}	1.00^{ab}	0.97^{bcd}	0.98^{ab}	1.09^{bcd}	1.20^{bc}	0.85^{a}
½" D	1.02^{a}	0.98^{ab}	0.83^{a}	0.77^{ab}	0.93^{a}	0.98^{ab}	0.92^{ab}	0.79^{a}
F NC	1.17^{bc}	1.18^{cd}	1.06^{ab}	1.04^{cd}	1.02^{ab}	1.22^{cd}	1.33^{c}	1.28^{b}
NF NC	1.18^{c}	1.27^{d}	1.18^{b}	1.11^{d}	1.15^{b}	1.25^{d}	1.33^{c}	1.36^{b}

Statistical Analysis Results for Aggregate Stability

Table C-14: Mean Soil Aggregate Stability Over Time at Four Sites. Values followed by different superscripts in each column are significantly different ($p < 0.05$)

Site	Clarence			Minisink			Rochester			Pine Island		
Date	6/05	9/05	6/06	6/05	9/05	6/06	6/05	11/05	6/06	6/05	9/05	7/06
¼" P	68.4^{a}	50.2^{a}	53.8^{a}	60.0^{a}	53.6^{ab}	57.5^{a}	46.7^{a}	48.9^{a}	32.5^{ab}	70.0^{a}	59.1^{a}	40.7^{a}
½" P	72.0^{a}	50.3^{a}	61.1^{a}	52.1^{ab}	59.8^{a}	57.1^{a}	45.0^{a}	47.7^{a}	39.2^{a}	77.3^{a}	50.7^{a}	30.5^{a}
¼" D	70.6^{a}	51.2^{a}	58.3^{a}	48.2^{ab}	43.7^{ab}	58.8^{a}	46.4^{a}	45.8^{a}	25.9^{ab}	60.2^{a}	50.4^{a}	34.5^{a}
½" D	77.3^{a}	48.7^{a}	54.5^{a}	57.1^{a}	52.4^{ab}	53.1^{a}	61.3^{a}	44.5^{a}	37.5^{a}	74.1^{a}	67.3^{a}	31.0^{a}
F NC	72.8^{a}	45.5^{ab}	50.6^{a}	42.8^{ab}	38.3^{ab}	49.5^{a}	50.3^{a}	33.1^{a}	25.1^{ab}	56.6^{a}	46.2^{a}	24.8^{a}
NF NC	74.7^{a}	32.2^{b}	47.2^{a}	35.0^{b}	32.7^{b}	58.1^{a}	49.4^{a}	38.5^{a}	19.3^{b}	49.2^{a}	45.3^{a}	37.1^{a}

TURF QUALITY

The turf quality data that were analyzed were percent grass, weeds and bare and an overall turfgrass quality rating. These data were collected approximately monthly during the growing season. For percent grass, weeds and bare, only treatment differences between the means at each of the observation dates was analyzed. For turfgrass quality ratings, in addition to treatment differences, linear regression over time was run. Since these data would be expected to go up and down depending on when the ratings were taken (i.e. lower turf quality would be expected at the end of the growing season than in the middle), linear regressions were performed only on the data taken in September and June of each year, just prior to compost application. All of the turf quality data were analyzed using the raw data.

Statistical Analysis Results for Percent Grass

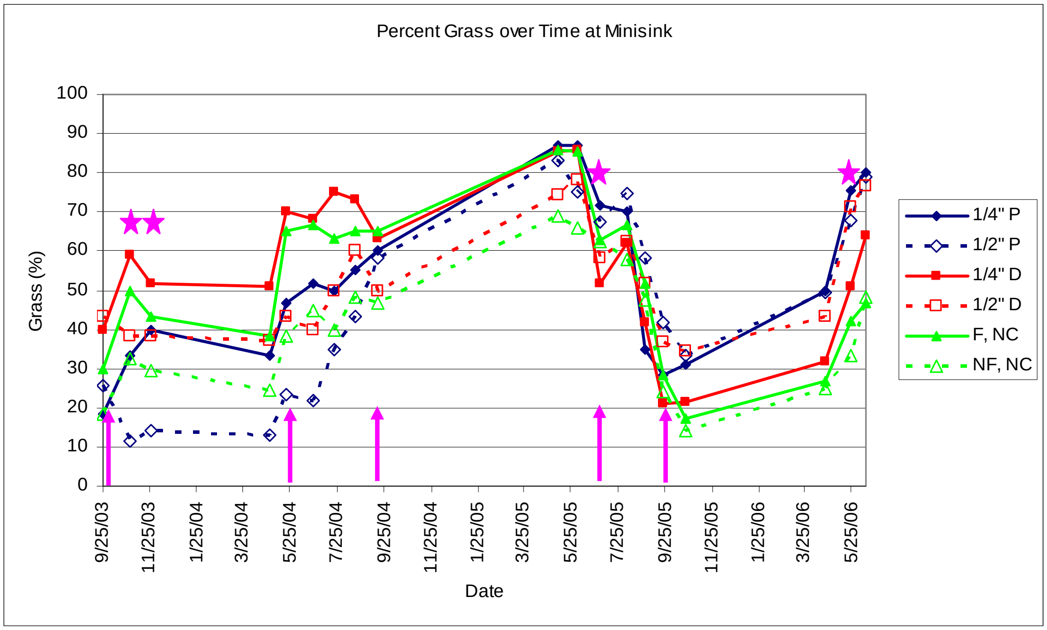


Figure C-1: Average Percent Grass Over Time at Minisink by Treatment. Pink arrows show compost application dates and pink stars show dates at which there were significant differences in percent grass between one or more treatments.

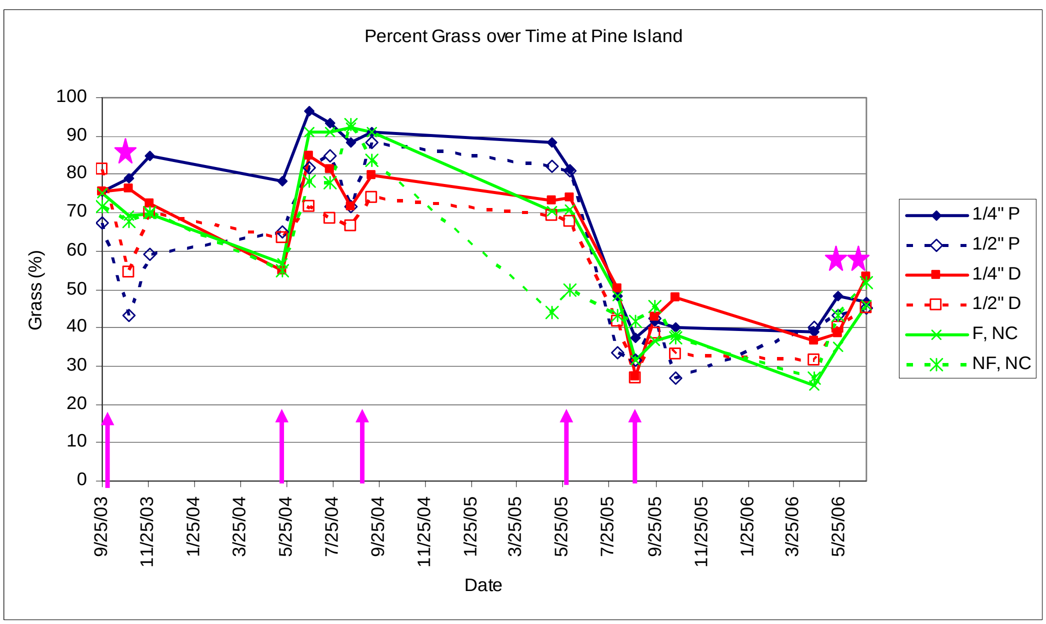


Figure C-2: Average Percent Grass Over Time at Pine Island by Treatment. Pink arrows show compost application dates and pink stars show dates at which there were significant differences in percent grass between one or more treatments.

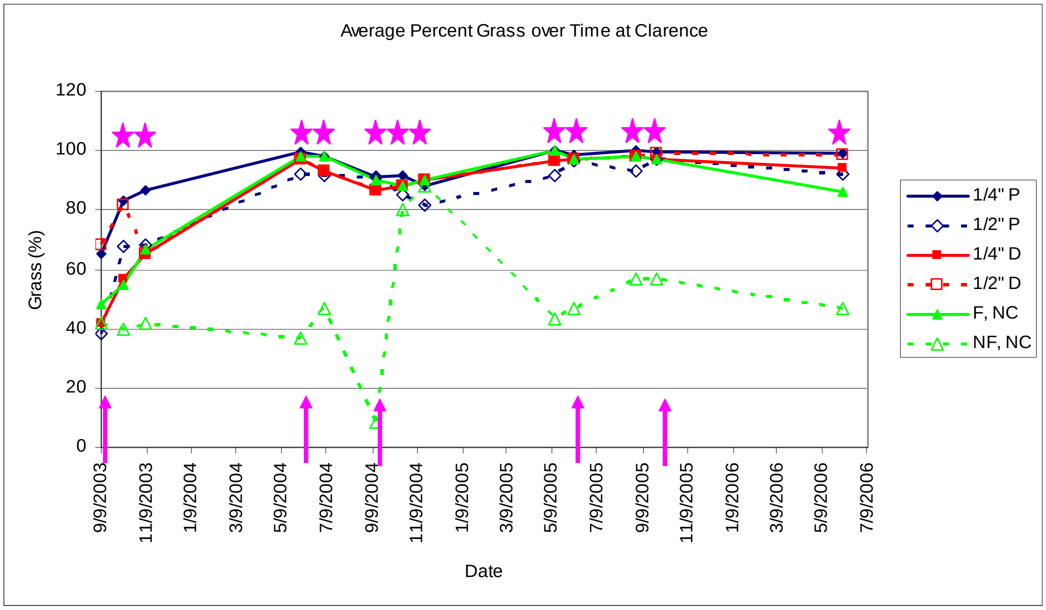


Figure C-3: Average Percent Grass Over Time at Clarence by Treatment. Pink arrows show compost application dates and pink stars show dates at which there were significant differences in percent grass between one or more treatments.

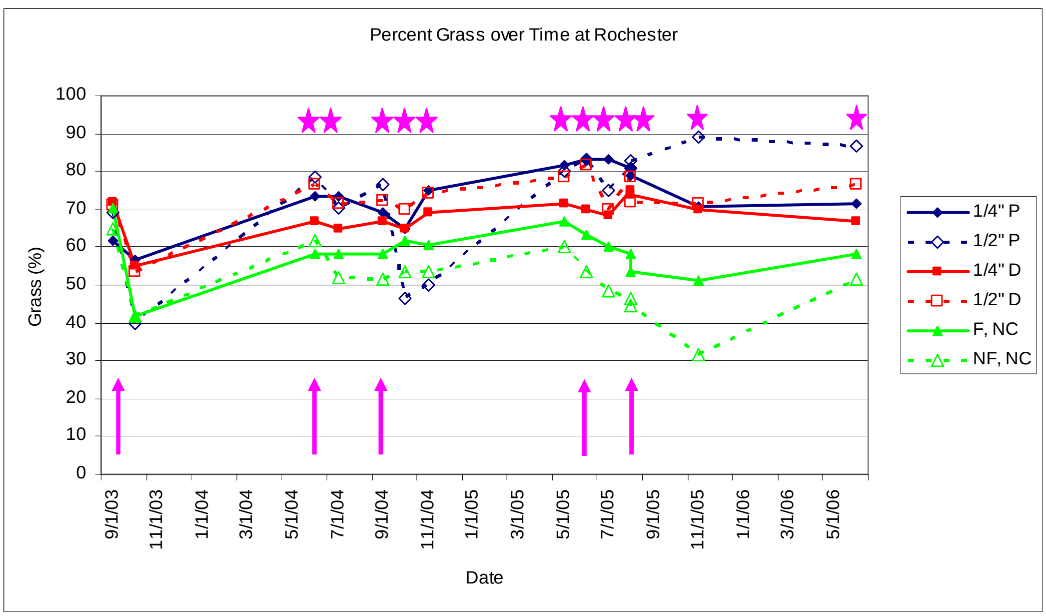


Figure C-4: Average Percent Grass Over Time at Rochester by Treatment. Pink arrows show compost application dates and pink stars show dates at which there were significant differences in percent grass between one or more treatments.

Statistical Analysis Results for Percent Weeds

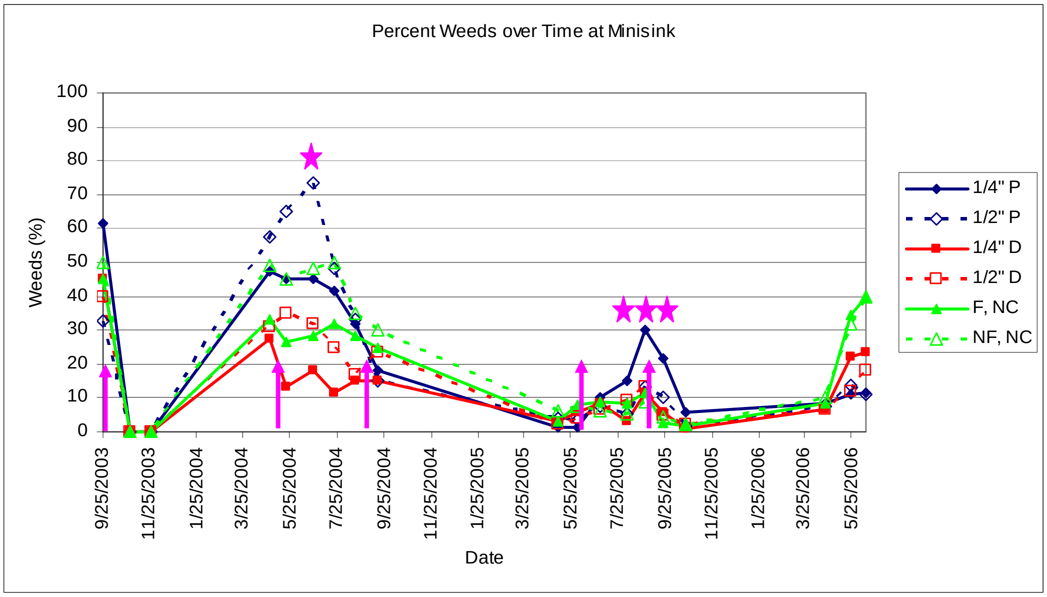


Figure C-5: Average Percent Weeds Over Time at Minisink by Treatment. Pink arrows show compost application dates and pink stars show dates at which there were significant differences in percent grass between one or more treatments.

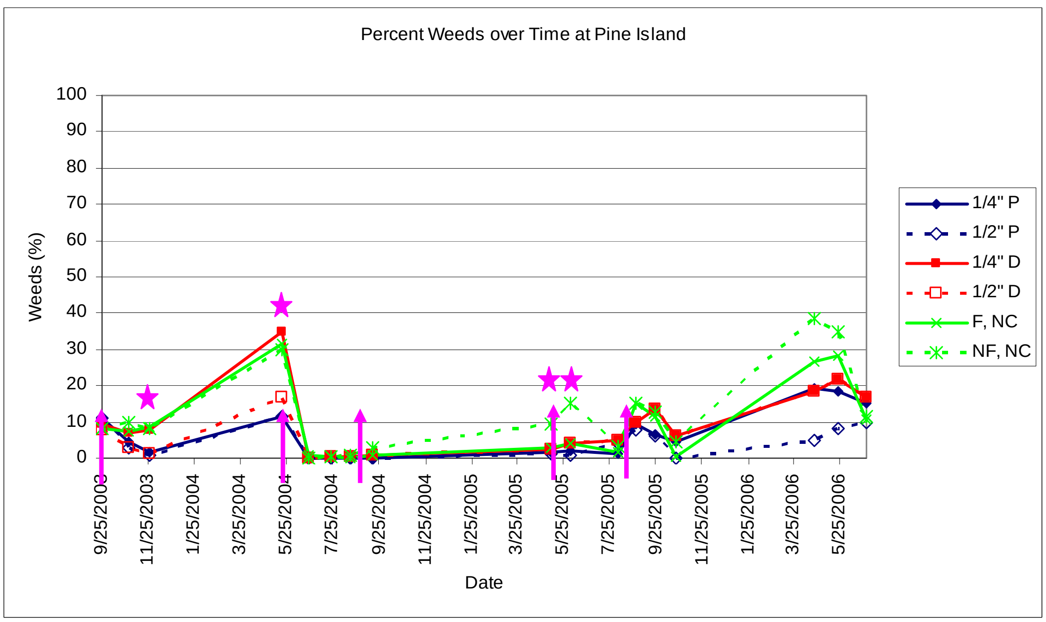


Figure C-6: Average Percent Weeds Over Time at Pine Island by Treatment. Pink arrows show compost application dates and pink stars show dates at which there were significant differences in percent grass between one or more treatments.

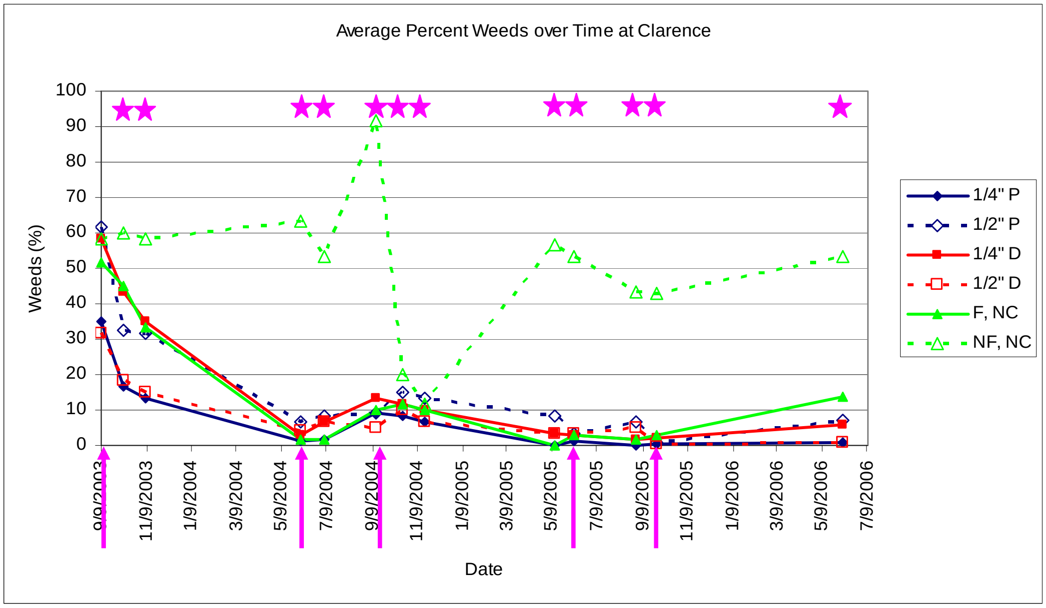


Figure C-7: Average Percent Weeds Over Time at Clarence by Treatment. Pink arrows show compost application dates and pink stars show dates at which there were significant differences in percent grass between one or more treatments.

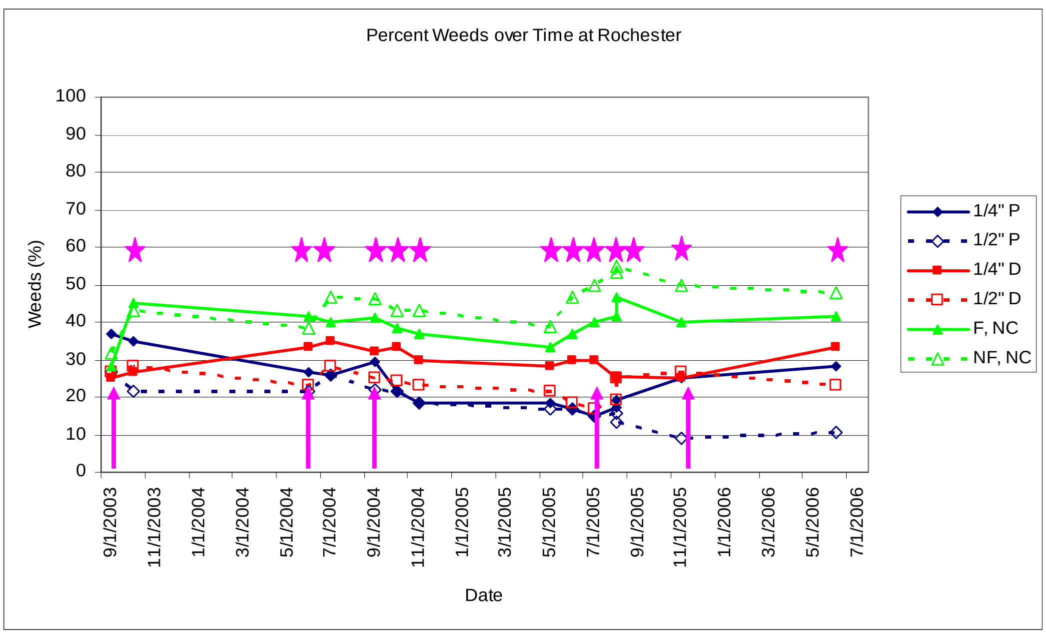


Figure C-8: Average Percent Weeds Over Time at Rochester by Treatment. Pink arrows show compost application dates and pink stars show dates at which there were significant differences in percent grass between one or more treatments.

Statistical Analysis Results for Percent Bare

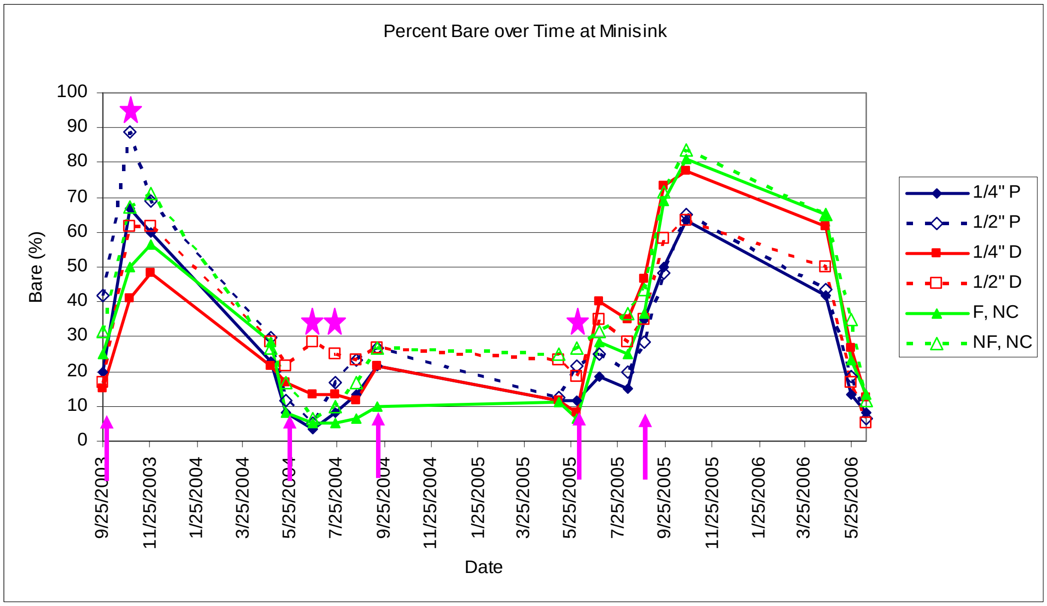


Figure C-9: Average Percent Bare Over Time at Minisink by Treatment. Pink arrows show compost application dates and pink stars show dates at which there were significant differences in percent grass between one or more treatments.

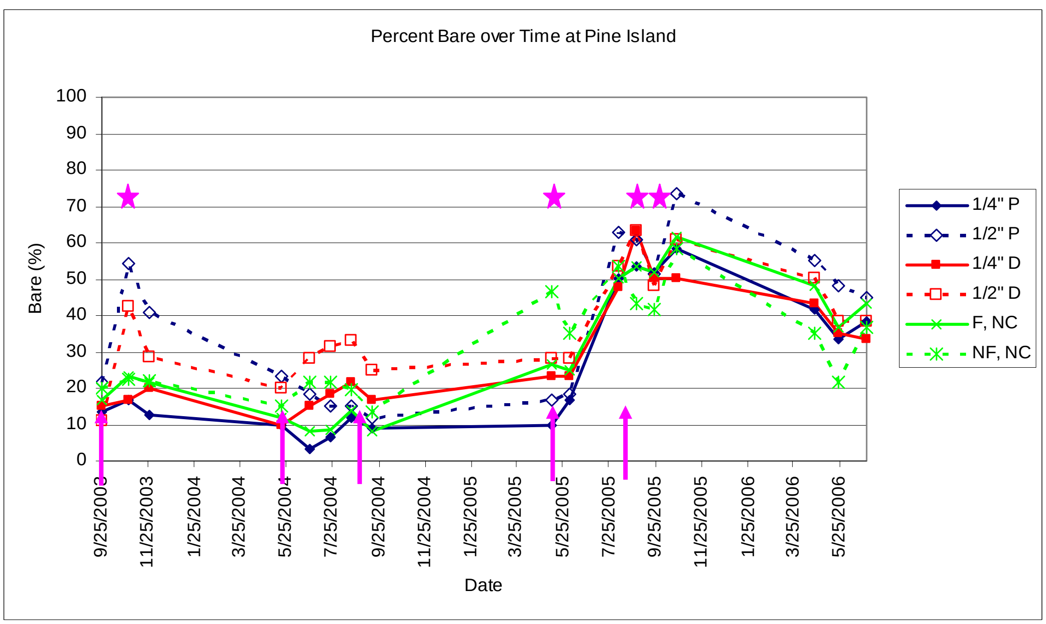


Figure C-10: Average Percent Bare Over Time at Pine Island by Treatment. Pink arrows show compost application dates and pink stars show dates at which there were significant differences in percent grass between one or more treatments.

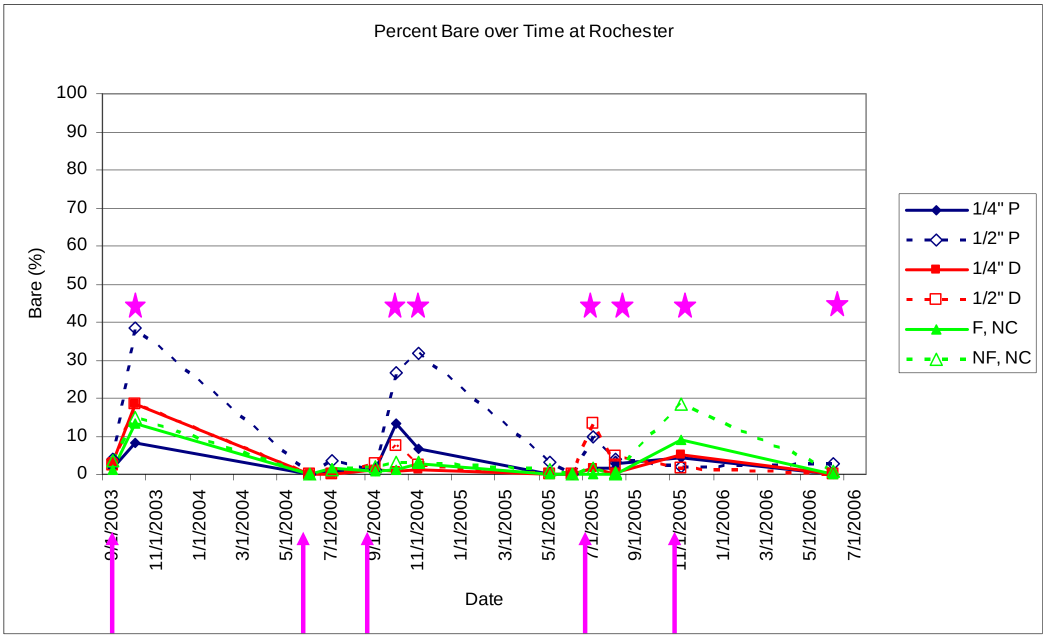


Figure C-11: Average Percent Bare Over Time at Rochester by Treatment. Pink arrows show compost application dates and pink stars show dates at which there were significant differences in percent grass between one or more treatments.

Statistical Analysis Results for Turfgrass Quality

Table C-15: Linear Regression Results by Treatment Over Time for Turfgrass Quality Ratings

Site	Treatment	Regression Line	p-Value	Multiple R^2
Clarence	¼" Poultry	y = 5.9 + 0.04x	0.0181	0.3021
	½" Poultry	y = 5.4 + 0.04x	0.0176	0.3045
	¼" Dairy	y = 5.5 + 0.05x	0.0125	0.3307
	½" Dairy	y = 5.9 + 0.03x	0.0250	0.2765
	Fertilizer, No Compost	y = 5.7 + 0.03x	0.0435	0.2309
	No Fertilizer, No Compost		Not significant	
Minisink	¼" Poultry		Not significant	
	½" Poultry	y = 3.7 + 0.06x	0.0096	0.3510
	¼" Dairy		Not significant	
	½" Dairy		Not significant	
	Fertilizer, No Compost		Not significant	
	No Fertilizer, No Compost		Not significant	
Rochester	¼" Poultry		Not significant	
	½" Poultry	y = 5.6 + 0.02x	0.0007	0.5245
	¼" Dairy	y = 5.6 + 0.01x	0.0168	0.3081
	½" Dairy		Not significant	
	Fertilizer, No Compost		Not significant	
	No Fertilizer, No Compost		Not significant	
Pine Island	¼" Poultry	y = 6.2 - 0.05x	0.0061	0.3833
	½" Poultry	y = 6.0 – 0.05x	0.0061	0.3841
	¼" Dairy	y = 5.9 - 0.03x	0.0177	0.3040
	½" Dairy	y = 5.7 – 0.04x	0.0053	0.5341
	Fertilizer, No Compost	y = 6.1 – 0.05x	0.0043	0.4085
	No Fertilizer, No Compost	y = 5.8 - 0.05x	0.0071	0.3726

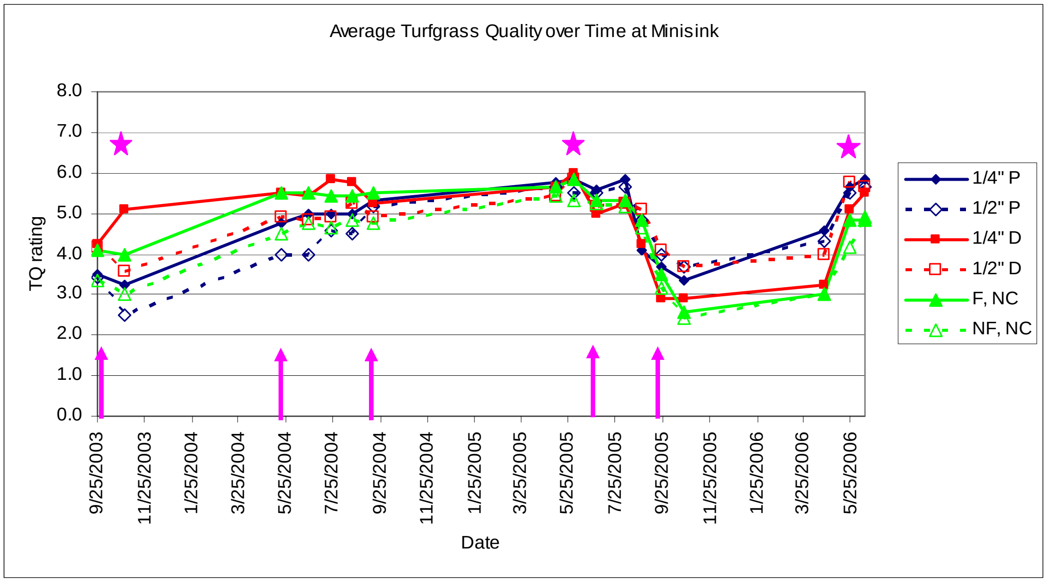


Figure C-12: Average Turfgrass Quality Over Time at Minisink by Treatment. Pink arrows show compost application dates and pink stars show dates at which there were significant differences in percent grass between one or more treatments.

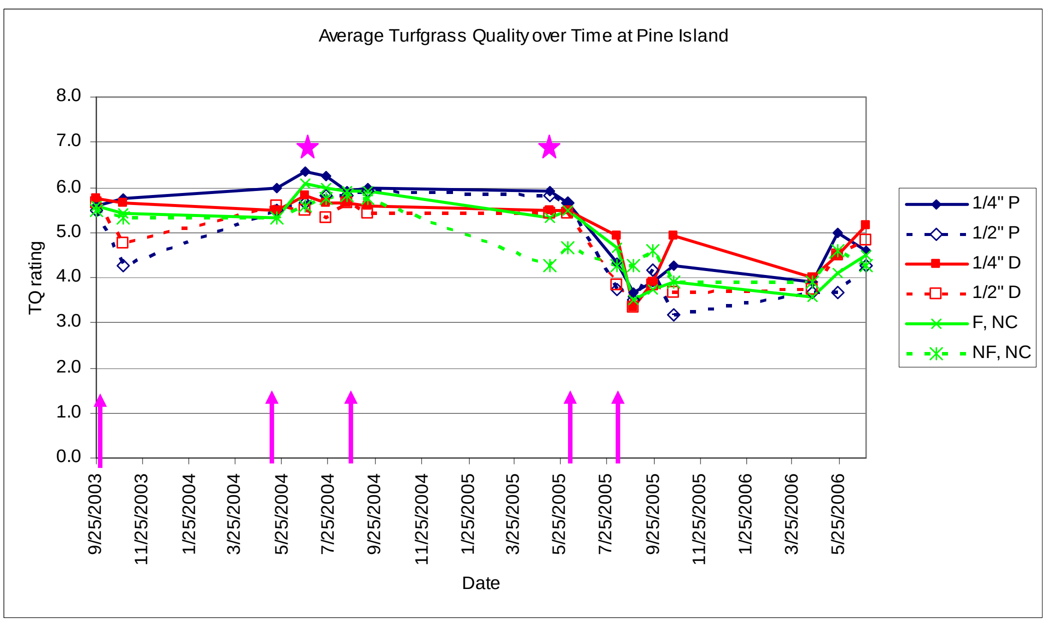


Figure C-13: Average Turfgrass Quality Over Time at Pine Island by Treatment. Pink arrows show compost application dates and pink stars show dates at which there were significant differences in percent grass between one or more treatments.

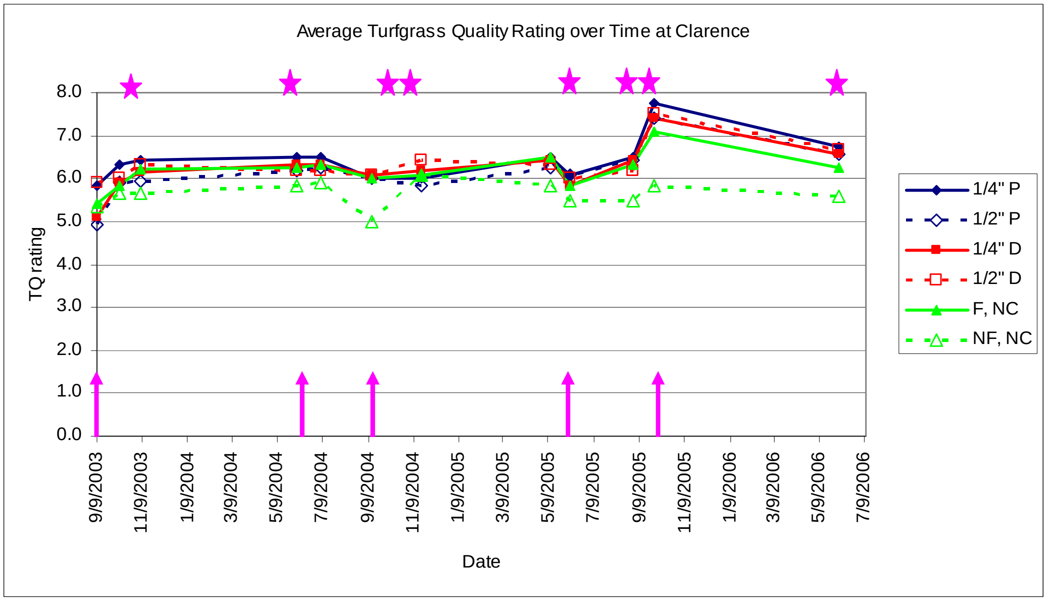


Figure C-14: Average Turfgrass Quality Over Time at Clarence by Treatment. Pink arrows show compost application dates and pink stars show dates at which there were significant differences in percent grass between one or more treatments.

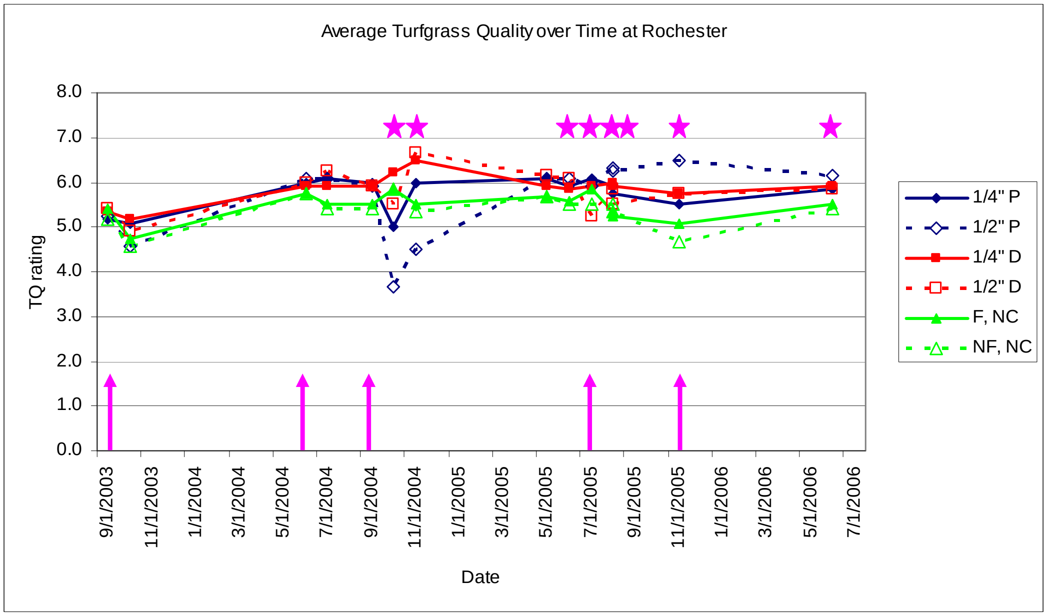


Figure C-15: Average Turfgrass Quality Over Time at Rochester by Treatment. Pink arrows show compost application dates and pink stars show dates at which there were significant differences in percent grass between one or more treatments.

INFILTRATION RATE

Table B-17 shows beginning (September 2003) and final (June 2006) infiltration rates at the 4 sites by treatment. Data for infiltration were analyzed using JMP statistical package on the log transformation of the raw data. Significant differences were determined using the Student's T-test.

Table C-16: Beginning and Ending Infiltration Rates (mm/hr) by Treatment at Four sites. Values followed by different superscripts within a column are significantly different ($p < 0.05$)

Site	Clarence		Minisink		Rochester		Pine Island	
Treatment	Sept 03	June 06	Sept 03	June 06	Sept 03	June 06	Sept 03	June 06
¼" Poultry	12.7^{ab}	35.5^{a}	1.4^{a}	5.0^{a}	6.3^{a}	11.8^{ab}	18.5^{a}	5.5^{a}
½" Poultry	10.2^{ab}	42.6^{a}	1.1^{a}	6.8^{a}	5.6^{a}	22.3^{a}	25.2^{a}	6.1^{a}
¼" Dairy	15.3^{a}	21.7^{ab}	1.0^{a}	6.9^{a}	4.4^{a}	11.4^{ab}	6.3^{ab}	5.5^{a}
½" Dairy	9.4^{ab}	24.3^{ab}	1.3^{a}	6.9^{a}	7.6^{a}	18.1^{ab}	11.3^{ab}	7.2^{a}
Fertilizer, no compost	6.4^{b}	13.8^{b}	1.1^{a}	4.7^{a}	6.3^{a}	9.0^{b}	12.1^{ab}	5.6^{a}
No fertilizer, no compost	11.8^{ab}	12.1^{b}	1.3^{a}	7.9^{a}	4.3^{a}	8.6^{b}	3.7^{b}	13.7^{a}

APPENDIX D

COMPOST TURF SITE OBSERVATIONS

MINISINK

Minisink represents a typical high-use sports field, with excessive use and highly compacted soils. The soil type is classified as a sandy loam. It is used for high school football practice and games and serves as the daily physical education outdoor site. This field was mowed twice a week at 2¼" to 2" and did not receive additional management.

Although the "non fertilizer" plots were tarped at the start of the study in 2004 the entire field was inadvertently fertilized. Therefore this site does not have the "no fertilizer" treatment.

In September 2003 at the start of the study grasses comprised 5-55%, weeds 30-80% and bare areas 5-60%. The entire area was rated below acceptable.

Table D-1: Site Observations Made by Local Cooperators, Green Industry, Site Managers and/or Cornell University Staff in Minisink.

Timing	Observations
September 2003	Grasses comprised 5-55%, weeds 30-80% and bare areas 5-60%. The entire area was rated below acceptable.
October 2003	The herbicide application worked to remove the weeds and none were reported this month. The field was in poor condition due to heavy use.
November 2003	The entire field was fertilized, overseeded and had bark mulch applied. There was a slight increase in the percent of grass in most plots.
April 2004	The weed pressure was apparent and ranged from 25-62% and the bare areas were 10-30%.
May 2004	Weed pressure decreased in some plots and a dense population of knotweed was found in the ½" poultry plots.
June 2004	There was not much difference noted in the dairy plots at either rate. Although the poultry plots were nice and green knotweed was flourishing too.
August 2004	The percent grass increased in most plots but with football practice in full swing the bare areas started to increase.
September 2004	All plots were still rated at unacceptable levels, the poorest being the "no fertilizer" no compost plots. The ¼" dairy performed better than the ½" dairy.
May 2005	The study did not receive any fertilization from our cooperator. Turf was thin especially in the no fertilizer no compost plots. The poultry plots had good color.

June 2005	The poultry plots had dense dark green turf except in heavily trafficked areas.
July 2005	The entire site was very moist, some mushrooms present. The composted plots looked green. The dairy plots were rated poor. Generally speaking the poultry plots were dark green and the ½" poultry rate had more turf density.
August 2005	The field was brown and dry except in the composted plots which were green in color. Later that month there was green up due to rainfall. Plots no longer stood out as green squares. The site was under attack by Japanese beetle grubs.
September 2005	The field had more moisture and was not as hard. Heavy use left wear areas on the yard lines and in the center of the filed. Still insect pressure could be seen and bare areas were 35-89%.
October 2005	There was lots of football practice so the field did receive some topdressing and overseeding to help deal with the bare areas. There were heavy rains the last 2 weeks so the grass greened up.
April 2006	Broadleaf weeds started to encroach (knotweed, dandelion, plantain) and the bare areas ranged from 25 – 80%.
May 2006	The field started to look good, grass seed germinating with the help of rainfall over a two week period. The field was cored. Lots of knotweed could be seen.
June 2006	In June an increase in turf could be found in all plots and a reduction in weeds. None of the plots reached acceptable level.

PINE ISLAND

The Pine Island site is a community recreation field that hosts 25-30 baseball games per season and a summer recreation program from July – August. Typically the site was mowed weekly at 3” and the fertilized plots received 1# of nitrogen at the time of compost application using 30-0-20.

This site had the poorest quality “soil”, which classified as a coarse sandy loam. It was established on rubble and had no more than 2-2 ½” of actual soil.

At the start of the study in September of 2003 the entire area was rated very low due to the high percentage of bare spots (5-40%).

Table D-2: Site Observations Made by Local Cooperators, Green Industry, Site Managers and/or Cornell University Staff in Pine Island.

Timing	Observations
September 2003	The entire area was rated very low due to the high percentage of bare spots (5-40%).

October 2003	In most of the ¼" poultry plots the percentage of grass was increased but in the ½" plots grass was decreased. In most of the ¼" dairy the grass was increased but grass was decreased in all of the ½" dairy plots. The poorest quality was found in the no fertilizer and no compost plots and the best color in the poultry plots.
November 2003	By November the field looked good and there was an overall improvement in density. Applications of compost encouraged grass growth which filled in bare areas. There was a slight decrease in weeds but the presence was obvious.
May 2004	Across the study the overall quality was reduced and the weeds exploded. Trimec was applied to deal with the broadleaf weeds.
June 2004	By June most of the plots had 70-95% grass and only a few weeds. The no fertilizer and no compost plots looked thin and had a pale color. The ¼" poultry plots had the darkest green color and the poultry plots had increased density and no bare spots. Broadleaf weed control allowed the grass density to increase but the ½" dairy application increased the percent of bare spots.
July 2004	Weeds were under control at this time. The ¼" dairy had a slight reduction in grass and the ½" dairy had an increase in bare spots and a decrease in grass.
August 2004	The field was under moisture stress and there was an overall slight reduction in percentage of grass. Weeds were under control and the best color was found in the poultry plots.
September 2004	Although the grass density improved by now the quality was still below acceptable.
May 2005	The poorest quality plots were those that did not receive fertilizer or compost. The darkest color was found in the ¼" poultry plots.
June 2005	Weed pressure was increasing and all plots had poor quality especially the no fertilizer no compost plots. It was a very dry month and the grass was going dormant and lots of Japanese beetles were found. (Many ant hills were noted on the non-composted plots).
August 2005	The grass was very dry and crispy. There was little color left on the compost treated plots and all other areas were brown. Later in the month some green clumps of grass appeared along with lots of weeds.
September 2005	The quality of the entire study was very poor this month.
October 2005	Rainfall allowed the grass to green up however the plots ranged only 20-50% in grass and 50-80% in bare spots.

April 2006	Lots of chickweed invaded the site along with some plantain. Dark green color could be found on poultry plots.
May 2006	There was some rain this month and the grass began to look good but there were lots of weeds present. Still no plots approached acceptable quality.
June 2006	There was significant rainfall this month and a decline in weed presence in most plots. (The area smelled as if it was sprayed).

CLARENCE

The Clarence site was established September 2003 on the far edge of a baseball field and typified a lawn more than a sports field in terms of the intensity of traffic and use. It was mowed weekly at 2" and did not receive supplemental irrigation.

The soil type is a loam and depending on soil moisture core samples of 1½ - 2" depth were taken. According to protocol fertilized plots received 1# of nitrogen per 1000 sq ft at the time of compost application using 32-0-0.

Table D-3: Site Observations Made by Local Cooperators, Green Industry, Site Managers and/or Cornell University Staff in Clarence.

Timing	Observations
September 2003	At the start of the project the site had a mix of desirable grasses (10-85%), weedy grasses and broadleaf weeds (dandelion and clover) and no bare areas.
October 2003	Negative effects of the ½" poultry application could be seen within a month of application. The ½" dairy application was visible and appeared too thick. The ¼" poultry and dairy applications showed comparable results.
January 2004	During this early site visit the composted plots appeared green especially for this early time of year. Total grass coverage improved.
March 2004	In January and March the composted plots appeared green at this early time of year. Total grass coverage improved.
June 2004	By June the plots which did not receive fertilizer or compost had a high percentage of weeds (50-80%) especially clover.
September 2004	The no fertilizer, no compost plots ranged 90-95% weeds in September.
October 2004	The October rating indicated that bare spots could be found in the plots that received ¼" and ½" of poultry.
June 2005	The weedy plots have remained weedy and the bare spots filled in. Most of the plots contained 95-98% grass and the best color was found in the ½" poultry plots.

September 2005	The plots received ~4" of rain. The best overall quality was found at the ¼" poultry rate, the ½" rate caused bare spots. Some of the best plots were the ¼" diary and the ½" rate provided high quality ratings.

ROCHESTER

The Rochester site was established in September 2003 on a soccer field which was used by both schools and the community for about 2 games per week. At the start of the study this site had about 54-79% grasses, 15-45% weeds and up to 10% bare areas. This site had moderate traffic throughout the study. The field was mowed at 2½", every 10 days and weed control was not used.

The soil type is a Niagara very fine sandy loam. Depending on soil moisture core samples of 2 ½ -3" depth were taken. According to protocol fertilized plots received 1# of nitrogen per 1000 sq ft at the time of compost application using 32-0-10.

Table D-4: Site Observations Made by Local Cooperators, Green Industry, Site Managers and/or Cornell University Staff in Rochester.

Timing	Observations
September 2003	At the start of the study this site had about 54-79% grasses, 15-45% weeds and up to 10% bare areas.
October 2003	October observations indicated that the ½" poultry application resulted in bare spots of 30-45%. No benefit was seen by the addition of compost. Lots of plantain and clover were present.
June 2004	An increase in grass could be seen in the study but the ratings still fell short of acceptance due to high percentage of weeds.
July 2004	This month was marked by high rainfall and the field was very wet.
August 2004	In the summer a heavy presence of clover was found (45-50%) in the plots which did not receive fertilizer and compost. The ¼" poultry application improved slightly.
October 2004	Bare spots were found where the ½" dairy application was applied too thickly. Burn spots were noted in the ¼" and ½" poultry plots. Plots on the north side of the study were rated very low due to excessive wear.
November 2004	The darkest green color could be found in the ½" poultry plots that earlier appeared to be burned.
May 2005	Lots of annual bluegrass creeping into the study. At this time no bare spots were present. Grass cover increased and so had weed pressure in some plots.

June 2005	There was a slight increase in desirable grasses as well as broadleaf weeds, clover and plantain.
July 2005	The poultry compost plots showed good dark green color and almost no clover present. Plots which received no fertilizer or compost contained 50% weeds and the plots that were fertilized but not composted had 40% weeds. Weeds were present at lower levels in the composted plots: ¼" poultry 15%, in the ½" poultry 10-20%, in the ¼" dairy 25-35% and in the ½" dairy 15-20%.
August 2005	Only the ½" poultry plots came close to having acceptable quality. Lots of clover could be found in the ½" dairy, no compost + no fertilizer and the fertilizer + no compost plots. Plantain was more noticeable in the no fertilizer + no compost plots.
November 2005	At this time the ½” poultry plots looked the best.
June 2006	The best color was found in the ½" poultry plots and they came close to acceptable. The poorest were the no compost + no fertilizer and the fertilizer + no compost plots.

Original compacted clayey soil at the site (1) was amended with 50 percent compost by volume and added to a depth of 18 inches (2). Three years later, the landscape is thriving (3) and soil remains below root inhibiting levels.

AMAZING RESULTS IN THREE YEARS

HIGHLY COMPACTED SOILS IMPROVED BY COMPOST USE

Cornell University study shows how manure-based compost has lasting benefits for growth and health of plants.

Mary Schwarz, Nina Bassuk, Jean Bonhotal and Ellen Harrison

COMPACTED SOILS are the ubiquitous result of urbanization and the building process — with their high bulk densities and low macroporosities that restrict root growth. Creating viable landscapes on severely degraded sites due to construction damage is a tremendous challenge for professionals in horticulture. At the same time, livestock farms — especially New York State dairies — are under increasing pressure to improve their manure management. Composting is one important option that can help to reduce odors and pathogens, while enhancing biosecurity on farms.

A three-year long project was conducted by Cornell University's Waste Management Institute and Horticulture Department to examine use of manure-based compost for disturbed construction sites. The objective was to amend a compacted clayey soil with two types of compost in a landscape setting so that beneficial levels of soil density, aeration and drainage could be achieved.

Research conducted by A. Rivenshield and Nina Bassuk at Cornell's Urban Horticulture Institute in 2001, demonstrated that compacted soils can be made productive again if appropriate types and volumes of composted organic matter are incorporated. Soil bulk densities were reduced to below root restricting thresholds with the addition of 33 percent compost (by volume) in a sandy loam soil and 50 percent compost in a clay soil. With this in mind, a thorough characterization of the "before" conditions at the site was performed, including soil texture and density, spatial variability, drainage, water-holding capacity, nutrient and microbial status. Soil from the site was taken to the lab and amended with two types of composts (poultry and dairy) at increasing levels to predict how much would be necessary to create beneficial conditions for plant growth. The dairy compost was manure, bedding and food scraps bulked with wood chips. The compost was made on a dirt pad in windrows with a high turning frequency. The poultry compost was poultry manure and bedding bulked with wood chips. This was also made on a dirt pad in windrows with a high turning frequency.

Soil was taken from the site and roughly sieved through an 8 mm sieve. Zero, 25, 50 and 75 percent compost of both types was added by volume to the soil. The soil was mixed and recompacted using a standard Proctor hammer protocol and tested for density, macroporosity and drainage. Four replicates of each type of compost-soil mixture were analyzed. Table 1 shows the bulk density and macroporosity of the initial soil tests run in the laboratory. Fifty percent amendment reduced the bulk density of the soil to below root inhibiting levels (1.45g/cc) for silty clay soil after recompaction.

The original soil was taken from the site and amended with 50 percent compost (by volume). Half was amended with poultry compost and half with dairy manure compost and then returned to the site and added to a depth of 18 inches. The site was approximately 75 by 50 feet. It was divided into the "triangle" (site 1) and "Warren" (site 2). Both the poultry and the dairy manure compost amended soils were used in the triangle and Warren.

Because this was a "real world" project

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Table 1. Average bulk density and macroporosity for different volumes of soil and compost. Values followed by different superscripts in each column are significantly different ($p < 0.05$).

Compost	% Volume	Bulk Density	Macro-porosity
None	0	1.81^{a}	0.59^{a}
Poultry	25	1.65^{b}	0.54^{a}
Poultry	50	1.51^{c}	1.24^{a}
Poultry	75	1.36^{d}	1.43^{a}
Poultry	100	1.22^{e}	1.49^{a}
Dairy	25	$1.56b^{c}$	0.84^{a}
Dairy	50	$1.28d^{e}$	1.08^{a}
Dairy	75	0.91^{f}	1.55^{a}
Dairy	100	0.51^{g}	4.99^{b}

Table 2. Average bulk density of the soil at the different site/compost combination over three years.

Date	Poultry Site 1	Poultry Site 2	Dairy Site 1	Dairy Site 2
12/3/04	0.81^{a}	1.13^{a}	0.85^{a}	1.01^{a}
11/3/05	0.67^{a}	1.12^{a}	0.82^{a}	0.98^{a}
9/21/06	0.80^{a}	1.15^{a}	0.97^{a}	0.94^{a}

Values followed by different superscripts in each column are significantly different ($p < 0.05$).

Table 3. Average macroporosity of the soil at the different site/compost combination over three years.

Date	Poultry Site 1	Poultry Site 2	Dairy Site 1	Dairy Site 2
12/3/04	6.1^{a}	3.3^{a}	4.0^{a}	3.2^{a}
11/3/05	3.0^{a}	3.3^{a}	3.8^{a}	3.9^{a}
9/21/06	3.8^{a}	3.0^{a}	4.3^{a}	4.1^{a}

Values followed by different superscripts in each column are significantly different ($p < 0.05$).

seeking to improve a degraded landscape, there were no unamended control plots. Soil samples of the amended garden soils were taken in quadruplicate from the different site/compost combinations on 12/3/04, 11/3/05 and 9/21/06 and tested for density, macroporosity and drainage. The bulk density and the macroporosity remained constant over time indicating that the benefits of compost addition lasted over three growing seasons (Tables 2 and 3).

The landscape is thriving and the bulk density of the soil remains below root inhibiting levels. The use of manure-based compost in soil remediation of construction sites can have lasting benefits for the growth and health of plants. ■

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Compost Utilization And Marketing

IMPROVING SOIL HEALTH

COMPOST USE ON ESTABLISHED TURF

Cornell University study on manure-based compost shows its effect on turf quality, organic matter content, nitrogen, phosphorus, water infiltration and nutrient availability over three-year period.

Mary Schwarz, Jean Bonhotal, Ellen Harrison, Joann Gruttadaurio and A. Martin Petrovic

A THREE-YEAR project conducted by the Cornell Waste Management Institute and the Department of Horticulture at Cornell University examined effects on soil and grass of topdressing manure-based composts on established turf fields. Funded by the New York State Energy Research and Development Authority and the Cornell Agricultural Experiment Station, this research explored markets for manure-based compost.

Turfgrass conditions on athletic fields are not only an aesthetic concern, but can have an effect on playability. Athletic fields are prone to compaction due to heavy traffic, use of fields when wet, and weight of vehicles used on the fields. Wet and/or hard surfaces can cause injury to the turf and the players. Compaction restricts rooting depth, reducing the uptake of water and nutrients by plants, which can lead to poor growth and loss of turf cover. Addition of organic matter to soil promotes aggregation of soil particles, increasing porosity and reducing bulk density to make a less compact soil.

An article in the July 2007 issue of *BioCycle* (p. 55) reported on our research findings regarding use of manure-based compost in landscaping on highly compacted soils. This article focuses on our research findings related to turfgrass.

Field research was conducted at four sites in New York State (NYS) from September 2003 through July 2006. At each site, there were six treatments in a randomized complete block design. Composts were applied five times. The composts used were analyzed prior to application for both pathogen levels (fecal coliforms and *Salmonella*) and compost quality parameters. Soil samples were taken for analysis of chemical and physical properties at the beginning and four times throughout the study. Turf quality was rated monthly during the growing season by trained professionals. Water infiltration rates were determined at the beginning and end of the study.

Two sites used in this study were located in western New York, and two in southeastern New York. The sites were very different in their use and management. At Site 1 in western New York, experimental plots were on the far edge of a baseball field in a park. The site was more like a lawn than a sports field in traffic intensity and use. It was mowed weekly at two-inches and did not receive supplemental irrigation, nor was there any weed control. The soil texture is a loam (43 percent sand, 17 percent clay). At Site 2, the experimental plots were on a soccer field used by both schools and the community for about two games per week. The site started out with about 60 percent grass, 30 percent weeds and 10 percent bare spots. It had moderate traffic during the study. The field was mowed at 2 1/2 inches every 10 days and weed control was not used. Soil texture

Two types of manure-based compost — poultry (left) and dairy (right) — from four different suppliers were used in this project.

is a very fine sandy loam (61 percent sand, 10 percent clay).

At Site 3 in southeastern New York, experimental plots were on a community recreation field that hosts 25 to 30 baseball games per season and a summer recreation program in July and August. It was mowed weekly at three inches. The soil here is a coarse sandy loam (66 percent sand, 11 percent clay) that was established on rubble and had no more than 2 to 2 1/2 inches of actual soil. At Site 4, experimental plots were on a high school sports field with excessive use and highly compacted soils. It was used for high school football practice and games. It also served as the daily physical education site. The field was mowed twice a week at 2 to 2 1/4 inches. Weed control was used. Soil texture is a sandy loam (68 percent sand, 8 percent clay).

MANURE-BASED COMPOST FROM FOUR SUPPLIERS

Two types of manure-based compost (dairy and poultry) from four different suppliers were used in this project. Table 1 shows the average range of properties of composted dairy and poultry manures used at the four sites for the three years of the study. Data on the quality of 25 manure-based composts in NYS (a previous study conducted by Cornell Waste Management Institute) can be found on the web at http://compost.css.cornell.edu/mlreport home.htm.

Each field had a 34 by 70 foot area designated for the experiment. There were eighteen 10 by 10 foot plots with a two foot buffer

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WEB EXTRA

Tables prepared by the authors with additional research findings can be found with the online version of this article on the BioCycle website. These tables include: Beginning and ending soil organic matter levels; Average soil bulk density, by plot treatment; and Beginning and ending soil P levels.

www.biocycle.net

Table 1. Average range of properties of composted dairy and poultry manures used over three years

Compost Property	*Dairy Compost Sites 1 and 2*	*Poultry Compost Sites 1 and 2*	*Dairy Compost Sites 3 and 4*	*Poultry Compost Sites 3 and 4*
Moisture (percent)	33 – 60	27 – 39	67 – 75	20 – 27
pH	7.9 – 8.5	8.8 – 8.9	7.4 – 7.9	6.9 – 8.0
Soluble salts (mmhos/cm)	1.5 – 4.3	7.7 – 9.9	1.0 – 4.4	10.9 – 13.1
Organic matter (percent dm basis)	23 – 39	44 – 56	49 – 64	35 – 43
Total nitrogen (percent dm basis)	1.2 – 1.6	1.8 – 2.2	1.6 – 1.9	2.5 – 3.0
Phosphorus (percent dm basis as (P_2O_5)[3]	1.0 – 1.4	5.0 – 6.4	1.1 – 2.1	4.0 – 5.7
C:N ratio	11 – 12	11 – 14	16 – 21	7 - 9

around each for three replicates of six treatments. Each site received five applications of compost. Because composts varied in moisture content and were applied on a volume basis, the dry weight (Table 2) and thus the quantity of nutrients, organic matter and other constituents added varied. Treatments started in September of 2003 and continued in June and September of 2004 and 2005. The treatments were: 1/4 inch layer of poultry manure compost; 1/2 inch layer of poultry manure compost; 1/4 inch layer of dairy manure compost; 1/2 inch layer of dairy manure compost; Fertilized control (no compost); Unfertilized control (no compost).

A core aerator (top) was used to help get the compost down into the soil. Plots (above) were core aerated before and after application of compost.

All plots, except the unfertilized control, received nitrogen fertilizer (no phosphorus) at the rate of 1 lb/1,000 sq. ft. At Site 4, however, after September 2003, all plots, including the "unfertilized" control, received fertilizer.

Prior to application of compost, soil samples were taken for chemical and physical analysis. The plots were then core aerated. Compost was weighed and applied on a volume basis (two bushel baskets per plot for the 1/4 inch rate and four for the 1/2 inch rate) and raked into an even layer on the plots. The plots were then core aerated a second time to allow the compost to mix with the soil. Unfertilized control plots were then covered with tarps and fertilizer was applied to the remaining plots. Water infiltration rates were determined at the beginning of the study in September 2003 and at the end in June 2006. Individual plots at all sites were rated monthly during the growing season for percent grass, weeds and bare spots and overall turfgrass quality rating using the National Turfgrass Evaluation Program (NTEP) method.

Table 2. Compost applied for each treatment at each site (tons/acre dry weight)

Site	*— Poultry Manure — (1/4-inch)*	*(1/2-inch)*	*— Dairy Manure — (1/4-inch)*	*(1/2-inch)*
1	11.7	22.7	12.5	25.5
2	11.1	22.1	12.7	25.8
3	14.2	28.8	6.6	12.5
4	14.4	28.9	6.6	13.4

One very important lesson learned from this project was that the properties of the composts can have an effect on the suitability of that compost for use on turf. For ease of application and transportation, moisture content is important. If it is too wet it will clump, and if it is too dry it may be dusty. Particle size is also important. Large pieces such as wood chips present a challenge to application and can also remain on the lawn surface and smother the turf. A maximum particle size of 3/8 inch is recommended. High conductivity (or soluble salts) can indicate that the compost is not fully mature and may "burn" the grass leaving voids that allow weed encroachment. Immature composts may also have an ammonia odor causing problems with players and neighbors.

ORGANIC MATTER, SOIL pH

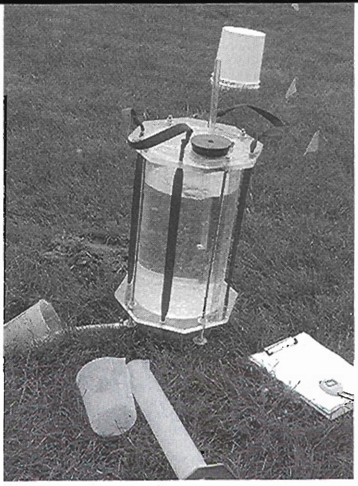
In this study, use of manure-based composts on turfgrass improved soil organic matter content, increased the pH of acidic soils closer to neutral, and decreased bulk density thus reducing compaction. For turf, soil organic matter values between 7 and 10 percent are considered acceptable. Soil organic matter levels increased significantly over time with all compost types and application rates at all sites, except Site 1, where 1/4 inch dairy compost did not cause a significant increase in organic matter over the course of the study. Compost application at Sites 2 and 3, especially poultry compost, brought the soil organic matter up from approximately five percent to between eight and 16 percent, greatly improving the organic matter content at these sites.

An improvement in the physical characteristics of the soils would be expected due to the increase in organic matter that resulted from the addition of compost; however, results were not uniform. Bulk density of the soils at all sites decreased over the course of the study on all plots due to the core aeration performed as part of the experiment. In addition, bulk density at the end of the study was significantly lower in one or more compost treated plots in comparison to the controls at two of the sites. At

Site 1, the 1/2 inch dairy treated plots had significantly lower bulk density than no fertilizer, no compost plots. At Site 2, all of the compost treated plots except 1/4 inch dairy had significantly lower bulk density than the no compost plots. At Sites 3 and 4, no significant differences were noted after three years of compost application in the bulk density of any of the plots.

Soil pH has an effect on the availability of soil nutrients. Most minerals and nutrients are more soluble or available in acid soils than in neutral or slightly alkaline soils. A pH range of approximately six to seven promotes the most readily available plant nutrients. Compost application did not have an effect at the western New York sites (1 and 2) where the pH averaged over all plots started at 7.4 and ended at about 7.6. At Site 3 where initial soil was acid, application of poultry compost over three years did significantly increase the pH from 6.1 to 7.2 for the 1/4 inch treatment plots and from 5.0 to 7.3 for the 1/2 inch treatment plots. The addition of 1/2 inch dairy compost at Site 3 increased the pH from 5.9 to 7.0. At Site 4, all of the plots, including the control plots, showed an increase in pH over the course of the study from just above six to around seven.

Application of manure-based composts increased available soil phosphorus (P) to levels that may cause concern about runoff or leaching losses of P. Levels of 4.5 mg/kg P are considered to be high and levels approaching 50 mg/kg may become an environmental issue as they are more prone to discharge P to the environment in water runoff. Soil phosphorus, which started high at Sites 3 and 4 and was optimum at Sites 1 and 2, increased significantly over time at all four sites on plots receiving compost. There was an immediate effect on soil P levels from the poultry compost, but it took longer to see an effect from the dairy compost. By the end of three years, all compost treated plots had significantly greater soil P levels than non-compost treated plots at Sites 1, 2 and 3. At Site 4 though, as P levels increased in the non-compost treated plots as well, only the 1/2 inch compost levels (both poultry and dairy) had greater soil P.



The rate of water infiltration into the plots was measured as part of the research study. At Sites 1 and 2, three of the four plots treated with poultry compost had higher infiltration rates than the control.

INFILTRATION RATES AND TURFGRASS QUALITY

The infiltration rate of a soil is the rate at which water soaks into it, measured as cm of water soaking in per hour. If the infiltration rate is very low, say less than 0.5 cm per hour, even very gentle rain falling on moist medium will cause surface ponding or runoff of water. Under such conditions, surfaces of playing fields will remain mushy for days after rain, allowing play to cause much damage to the turf. Infiltration rate is a useful indicator of aeration in the soil. Good aeration is probable if the infiltration rate is greater than 2 cm/h. Poor turf growth can be traced to poor aeration of the root zone. The approximate infiltration rate of loam soils is between 0.5 and 2.0 cm/hour depending on type of loam. Initial infiltration rates at all sites were within this range. At Site 1, both poultry treated plots and at Site 2, the 1/2 inch poultry plots had significantly higher infiltration rates than the control plots at the end of the study. There were no differences between plots at the end of three years at Sites 3 and 4.

Over the three years, at Site 2, compost additions improved turfgrass quality. At all sites, compost additions improved grass cover and reduced weeds in the short term, but these changes did not persist into the next season. In addition, many of the managers at the sites reported earlier spring green-up on the compost-treated plots, possibly related to the addition of iron. However, at some sites high salt levels and immature composts had detrimental effects such as burning of the grass that resulted in leaving voids that resulted in exacerbation of weed problems. On sites where fields were poorly constructed and where field-use was very high, compost additions could not overcome these limitations and did not result in significant improvements in turf quality. ■

The authors are members of the Cornell Waste Management Institute and Department of Horticulture at Cornell University in Ithaca, New York. For a complete report go to http://cwmi.css.cornell.edu/turf.htm.